UNDERSTANDING TEAMWORK IN TRAUMA RESUSCITATION THROUGH ANALYSIS OF TEAM ERRORS

By

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ABSTRACT OF THE DISSERTATION

Understanding Teamwork in Trauma Resuscitation Through Analysis of Team Errors

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An analysis of human errors in complex work settings can lead to important insights into the workspace design. This type of analysis is particularly relevant to safety-critical, socio-technical systems that are highly dynamic, stressful and time-constrained, and where failures can result in catastrophic societal, economic or environmental consequences. Some examples of such systems include an airplane cockpit, the stock market, a hospital, and a nuclear power plant. The research described in this dissertation focuses on advanced trauma care, an additional example of a socio-technical system in which medical teams use complex work processes while treating severely injured patients early after injury. Despite advances in trauma care over the past few decades, errors are still observable, even among the most experienced teams. This dissertation focuses on teamwork errors. It identifies and analyzes why, when, and how teamwork errors occur in trauma resuscitation. The objective was to gain deep insights and knowledge of the work of trauma teams to inform the development of information technologies to support teamwork and detect and prevent errors. Through an extensive ethnographic study and a mixture of techniques including cognitive work analysis and grounded theory approach, four team error types were identified. These include: interpretation errors, caused by inefficient evidential data integration; communication errors, caused by failures to report critical patient information; management errors, caused by inefficient tracking of the progress of multi-step procedures; and, concurrency errors, caused by parallel activities over the shared resources. Findings from this study have broader applicability to other collaborative and highly dynamic work settings that are prone to human error. This work contributes to the fields of Information Science and Computer-Supported Cooperative Work by adding to the understanding of collaborative information seeking in large collocated teams; identifying the challenges and opportunities for information technology support of teamwork in time- and safety-critical settings; and, providing specific recommendations for technological support of teamwork in trauma resuscitation, a domain of great societal importance.

Acknowledgment

I once read that the ideal PhD student is the one who tells the advisor what his or her thesis should be and carries it out independently. As PhD students, we strive to reach this ideal, but it becomes clear pretty soon that we cannot do it alone. We need an ideal advisor, too. We need a person who will teach us how to become independent thinkers, inventors, and problem solvers. Throughout the years I spent as a PhD student at the School of Communication and Information, I was fortunate to be advised by such a person, Professor Michael Lesk. I am truly thankful for his wisdom, kindness and support that have guided me throughout this research. I am particularly thankful for his encouragement to take on a research project in an area we both knew little of. As it happened, the journey we took proved to be challenging yet rewarding. We learned a lot from each other and enjoyed working together on every bit of this project. Every PhD student should have an advisor as good and generous as Michael.

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Dedication

In memory of my father, Vinko Sarcevic.

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Chapter 1

Introduction

1.1. Chapter Overview

This thesis focuses on teamwork in *trauma care*, a domain in which medical teams use complex communication and work processes while engaged in time-critical activities. The goal was to identify human errors unique to trauma teamwork and explain their causes using ethnographic analysis. The purpose of this chapter is to provide an overview of the research domain, a statement of the problem, research goals, and significance of this work.

1.2. Research Domain

An analysis of human errors in complex work settings can lead to important insights into the workspace design. This type of analysis is particularly relevant to safety-critical, socio-technical systems that are highly dynamic, stressful and time-constrained settings, and where failures can result in catastrophic societal, economic or environmental consequences. Functioning of these systems depends on the work of knowledge-based teams that use complex communications and processes to achieve their goals. Some examples of safety-critical, socio-technical systems include an airplane cockpit, the stock market, a hospital, and a nuclear power plant (Vicente, 1999). Since the 1970s, researchers have studied a variety of factors that affect task performance and lead to errors in safety-critical environments. Their main motivation was to understand the nature of these application domains and provide design recommendations for technology support (Johnson, 1999). This previous work has yielded progress in some domains where computer systems can now directly perform internal rule checks on user input to recognize and prevent errors. For example, a command to the system in an airplane cockpit to fly to a dangerously low altitude prompts a warning or blocks its execution (Hourizi & Johnson, 2001). This type of computer support requires sensors or other instrumentation that accrue situational information needed for detecting problems and issuing relevant warnings.

The research described in this thesis focuses on *advanced trauma care*, an additional example of a domain in which medical teams use complex work processes while treating severely injured patients early after injury. Trauma resuscitation is a safety-critical, high-risk medical environment that has received little study from the perspective of human work. The purpose of trauma resuscitation is to stabilize the patient, determine the extent of the injury, and develop a treatment plan to be carried out during hospitalization. It is a highly dynamic process prone to human errors even among experienced trauma teams (Clarke et al., 2000; Gruen et al., 2006). Although considered as a complex socio-technical system, trauma resuscitation lacks effective information technologies for preventing or alerting to errors. Unlike in an airplane cockpit, there is no system to capture worker activities and monitor for errors. Errors are now prevented through care-provider experience, training and redundancies in the evaluation process. Trauma bay instruments, such as a vital signs monitor, only provide data about patient status. There is no technology to aid in decision making, which primarily relies on care providers' knowledge and judgment. Team members must remember to monitor screens and observe trends in the data with audible alerts available only for extreme values. Monitoring of instruments is visual (e.g., looking at the monitors) or aural (e.g., listening for pattern changes in the continuous alert sounds). Relevant patient findings, test results, and observations are called out and exchanged verbally between pairs, small groups, or the entire team. Critical patient data is recorded manually even when digital devices are used for data acquisition. X-rays are viewed on an electronic monitor but no alerts announce when the images are ready for viewing.

The work characteristics described above vary from trauma center to trauma center. As of March 2008, the United States had 1,395 designated trauma centers (MacKenzie et al., 2003; see Trauma Information Exchange Program Report for recent updates). The quality of care that is provided at these trauma centers varies based on several factors including the immediate availability of trauma surgeons and other specialists, facility resources and teaching and research capabilities. To account for these differences and the spectrum of care provided at different trauma centers, the American College of Surgeons established a classification scheme by which trauma centers are ranked into four levels (American College of Surgeons). According to this classification scheme, Level I trauma centers have the capability of providing extensive care for every aspect of injury; they also have a large number of personnel and facility resources and the responsibility of providing leadership in education, teaching and system planning. In contrast, Level IV trauma centers provide only basic life support before patient transfer to a higher-level facility. Thus, the statement that work characteristics described above vary from trauma center to trauma center is valid. Still, the author of this thesis believes that despite these differences, the challenges faced by trauma teams remains the same across all levels: patients with unstable or fluctuating medical status, unknown medical histories, multiple sources of conflicting and often incomplete information, intense time pressure and variable knowledge and expertise of team members. Various trauma teams may process the information more or less efficiently, and some trauma centers may be more technologically advanced than others. However, regardless of the trauma center, the key tasks remain and the means for performing the tasks are standardized throughout the US. All trauma centers use a standard protocol called Advanced Trauma Life Support or ATLS (American College of Surgeons, 2008) that has been developed to guide the initial evaluation and management of injured patients. Additionally, team composition and staffing are similar at most trauma centers in the US (R. S. Burd, personal communication, March 10, 2006).

Designing technology-based support for human-machine interaction in work domains that are primarily social in nature and governed by human intentions is difficult. To date, it is not even known whether computer aids for trauma resuscitation should support certain individuals, the overall team, or both. Research efforts have so far been unsuccessful in developing information systems to aid complex activities of trauma teams (Clarke et al., 2002; Garg et al., 2005; Gertner et al., 1997). The key reasons for this include the challenge of acquiring information from diverse sources in a dynamic environment, the difficulty of synthesizing acquired information into meaningful output and recommendations, workers' resistance towards technology and the stringent requirement of a fail-safe system. Additional challenges to the application of information technologies in this domain include communicating in a stressful and noisy environment; minimizing errors during the time-constrained evaluation of the patient; interacting with computers while having hands and eyes busy with the main task of patient care; adjusting evaluation protocols for differences in team size, expertise and the degree of injury; and, supporting collaborative activities of evaluation and treatment.

Trauma resuscitation as a research setting is of interest for several reasons. The trauma bay, a designated area in the emergency department (ED) for conducting trauma resuscitations, is a stressful, noisy and dynamic environment in which information that guides decision making comes from a range of sources, including both the internal data sources within the trauma bay and external sources from the injury scene or from the hospital. This environment shares several attributes of other, safety-critical, socio-technical systems including (a) an unpredictable set of problems, (b) the occurrence of incomplete or conflicting information, (c) multiple and sometimes conflicting goals, (d) intense time pressure, (e) a low margin for error, and (f) variable knowledge and expertise of team members. As such, it represents an extremely error-prone environment, and is ideal for studying human errors. Additionally, trauma resuscitation provides a valuable site for the study of cooperative work because the task demands change rapidly and vary in nature, predictability, and difficulty. This is in contrast to other clinical settings in which patient management relies on existing rather than emerging information.

This thesis is part of a larger research effort jointly conducted by the faculty from Rutgers University and trauma surgeons from UMDNJ-Robert Wood Johnson University Hospital (RWJUH), New Brunswick, NJ, and Children’s National Medical Center, Washington, DC. Our long-term goal is to address the question of how to successfully design and implement computer-based support to improve information gathering and sharing, decision making, and error detection during dynamic and safety critical teamwork, such as trauma resuscitation. This thesis, however, completes only the first step towards reaching the above-mentioned goal: an in-depth analysis of trauma teamwork to identify teamwork errors and their causes, as well as the requirements for technological solutions that could potentially reduce them.

1.3. Statement of the Problem

Trauma care is complex, critically important, and expensive. It is a significant public health problem in the US and worldwide and remains the leading cause of death and disability in children and young adults (Stewart et al., 2003). During trauma resuscitation, potentially life-threatening injuries are rapidly identified and treated, and plans for subsequent hospitalization are developed. The initial resuscitation is prone to errors because care providers often manage patients with unstable or fluctuating medical status, whose detailed medical history is commonly not available, and whose care requires time-critical decisions.

Managing critically ill patients is essentially “the art of managing extreme complexity” (Gawande, 1997). Donchin et al. (1995) noticed that the patient in a critical care setting requires more than 170 actions per day. When errors occur only in 1% of these tasks, this translates to two errors per patient per day. Checklists have been found to be a simple method for improving team performance when routine tasks can be identified (Reason, 2002). As an example, a checklist for verifying the safety and efficiency of inserting intravenous lines lowered the infection rate by 11% at one institution, preventing an estimated eight deaths and saving $2M in just over one year (Wu et al., 2002). Because trauma disproportionately affects the young, injury takes more years of life than cancer and cardiovascular disease combined. In addition to lives lost, care of injured patients in the US consumes more dollars than is spent on either cancer or cardiovascular disease (AHRQ, 2006). Although error reduction is important in reducing these costs, improving efficiency of early trauma care can also be anticipated to have an important dividend since each minute of delayed care can increase mortality by as much as 0.5% among patients with life-threatening injuries (Clarke et al., 2002).

Despite process standardization and highly trained personnel, human errors and inefficiencies are still observed during trauma resuscitation (e.g., Clarke et al., 2000; Gruen et al., 2006). As research has shown, errors disrupt the flow of care, slow the speed and efficiency of the evaluation, and may have cascading effects leading to poor patient outcome. Many factors can lead to errors, including language and communication barriers (e.g., Bard et al., 2004; Bergs et al., 2005), as well as inter-professional relationships (Cole & Crichton, 2006). Errors may also occur because of missing or incorrect information (Clarke et al., 2000). Previous work on error causation (reviewed in Chapter 2) has so far only suggested priming factors for medical errors during trauma resuscitation. These include:

- *Patient factors*: trauma patients often have unstable or fluctuating medical status and require time-critical decisions that must be based on limited or fragmentary data.
- *Care provider factors*: reliance on provider attentiveness and memory to follow ongoing evaluation and monitor changes in continuous vital sign data; provider fatigue; distractions from task performance and decision making, such as multiple injuries, answering questions by other team members, and background noise in the emergency department.
- *Organizational and system factors*: transfers of care requiring data exchange between emergency medical services (EMS) personnel, trauma team and in-

hospital providers; dynamic flow of participants in and out of the trauma bay; fluctuation of the trauma team membership from day to day and even shift-to-shift; poor integration of observed data between team members because of redundant paper-based records; incompatible hospital information systems mandating manual transfer of data to a common record; hierarchical team structure that may inhibit bidirectional information exchange.

In contrast to individual worker's errors, little is known about errors that are unique to teamwork. Previous work offers a preliminary theoretical framework for understanding team errors (e.g., Sasoua & Reason, 1999; Treppes & Stockman, 1999), but there are important gaps in knowledge that need to be addressed to achieve practical system designs (Johnson, 1999).

This thesis is a step toward filling these gaps. It examines why, when, and how teamwork errors occur in trauma resuscitation. The objective was to gain deep insights and knowledge of the work of trauma teams to inform the design and development of support technologies to detect and prevent errors in this safety-critical domain.

1.4. Research Goals

The purpose of this thesis is to identify and explain the causes of errors unique to teamwork in a complex, time- and safety-critical setting of trauma resuscitation. To achieve this goal, one must also acquire a thorough understanding of the work domain, i.e., the nature of trauma teamwork. To that end, this thesis provides descriptions of trauma teams and their work, including the process, tasks and goals in trauma resuscitation. It also examines decision-making and communication practices, information flow and the information needs of trauma teams. By developing a thorough understanding of the trauma resuscitation domain and identifying errors and their causes, important insights can be gained into the challenges that computerized support must meet to facilitate cooperative work in high-risk environments.

1.5. Perceived Significance of This Research

The results of this research contribute to the advancement of science by exploring collaborative activities of a multidisciplinary team that is engaged in a complex, real-world dynamic task that is unpredictable, time critical, and cognitively consuming.

In short, this study results in a new understanding in the following areas:

- *Human Information Behavior*: The study contributes to the advancement of knowledge about the information seeking behavior of a specific group of users (i.e., trauma team members) in a specific setting (i.e., an emergency room) not yet investigated from this perspective.
- *Human-Computer Interaction (HCI)* and *Computer Supported Cooperative Work (CSCW)*: The results of this study inform the design of information systems to support the collaborative work of groups and teams in dynamic and time-critical work settings.
- *Healthcare*: The study contributes to the understanding of human errors and inefficiencies in trauma resuscitation. It explicates the tacit work practices and procedures, and examines the social organization of collaborative work and task coordination within trauma resuscitation.

There are three potential applications of the results that will be obtained by this thesis, all with the purpose of *reducing medical errors and improving the efficiency of trauma teamwork*:

1. Design of an integrated information capture and display system to provide computer-based support for trauma teamwork;
2. Technology development for real-time detection and prevention or repair of errors and inefficiencies;
3. Improved training of trauma teams and the potential re-design of the trauma resuscitation process.

1.6. Thesis Outline

The thesis is structured as follows. Chapter 2 is presented to delineate previous work that has looked at collaboration and human errors in time- and safety-critical domains, and to explain how the current work differs. Chapter 3 introduces research questions that have been answered by this work and presents an overview of the research framework that this thesis has adopted. Chapter 4 is presented to describe the methods that have been used to collect the data needed for answering the posed research questions. Also included in this chapter are the methods that have been used to analyze the data from the field. Chapters 5 and 6 present the findings of this work. In particular, Chapter 5 describes the trauma resuscitation domain, the goals, tasks and work organization of trauma teams. Chapter 6 presents a model of trauma teamwork along with detailed descriptions of trauma teams' work processes and observed inefficiencies, and a novel, team error classification scheme. Chapters 7 and 8 are presented to discuss the results this work has yielded, as well as challenges in designing computerized systems to support the work of trauma teams. Finally, conclusions, study limitations and areas of future work are discussed in Chapter 9.

Chapter 2

Literature Review

2.1. Chapter Overview

Prior work relevant to the problem addressed in this thesis spans three research areas: (1) modeling of collocated, time-critical teamwork, (2) analysis of human error and errors in trauma resuscitation, and, (3) development of computerized decision support for collocated teams in time- and safety-critical work settings. Each of these research areas provides useful and necessary insights into different aspects of trauma teamwork. The purpose of this chapter is to review the literature in the above areas of research and to differentiate the novelty of the work described in this thesis from the work done previously.

2.2. Modeling of Collocated, Time-critical Teamwork

2.2.1. Collaborative work in non-medical work settings

A number of studies of collaborative work have addressed time criticality outside of the medical domain, but have mainly focused on collaboration between pairs and small groups, rather than on collaboration in large, collocated teams. Seminal studies of work practices and procedures in traffic control rooms (Heath & Luff, 1992; Bentley et al., 1992; Berndtsson & Normark, 1999) have recognized an extensive need for communication and work coordination in the control of trains and aircraft as they move across physical sectors of responsibility. Through an ethnographic approach, these studies identified essential features of cooperative work in control rooms, some of which include: continuous flow of information among workers, simultaneous monitoring of co-workers' activities, and reliance on various information displays. Similarly, in his study of collaboration on a navigation bridge, Hutchins (1995) found that navigation teams maintain system robustness by redundant distribution of knowledge among team members, members' access to one another's activities and mutual monitoring and assistance supported by light individual workloads. These researchers proposed a set of design recommendations for information systems to support collaborative work and decision making in time- and safety-critical settings, two of which are applicable to trauma resuscitation: (1) systems should facilitate distribution of information about changes in the field; and, (2) systems should support both the systematic and informal practices of exchanging information between staff.

The above studies of teamwork in traffic control-rooms and ships' navigation bridges address collaboration between small groups of professionals (up to five). The work described in this thesis, with its detailed analysis of trauma teamwork, contributes to this body of research by providing new insights into the collaboration of larger groups (up to 15 professionals) in time- and safety-critical work settings. More importantly, while this previous line of research has greatly deepened our understanding of collaborative work in high-reliability teams, it mostly focused on the processes and work strategies that help the teams maintain failure resistant performance. The work described in this thesis differs from prior work in that *it examines the situations in which failures occurred*, and explains the causes of those failures.

2.2.2. Collaborative work in medical work settings

Collaborative work in healthcare has been studied extensively in both human-computer interaction (HCI) and computer-supported cooperative work (CSCW), in the so called "workplace studies" (Heath et al., 2000). These studies have mainly focused on the social and interactional character of organizational activities in operating rooms, anesthesia, and hospital wards (Bardram 2000; Hindmarsh & Pilnick, 2002; Moreira 2004; Svensson et al. 2007). Workplace studies typically adopt ethnomethodology as their primary method (Garfinkel, 1967), and rely heavily on repeated scrutiny of video recordings capturing talk and the interaction of group members in their everyday work settings (Heath & Hindmarsh, 2002). While effective in explicating teamwork practices, this approach does not lead to specific design requirements that might better support a team; it only provides pointers to appropriate design decisions (Hughes et al., 1992). Also, ethnomethodology is impractical for studying trauma resuscitation given the difficulty of acquiring access to this domain and the inability to use video recordings for extended periods. Most importantly, the workplace studies rarely considered errors and inefficiencies in the work processes of medical teams, which is the key contribution of this thesis.

Nevertheless, the workplace studies are relevant to the work described in this thesis because they suggest that hospital wards and operating rooms can be viewed as complex socio-technical systems in which technologies, people, and organizational routines dynamically interact. Likewise, trauma centers can be viewed as complex socio-technical systems despite the fact that they lack sophisticated technologies for supporting workflow and communication among the actors involved. Bardram (2000) discussed temporal aspects of coordinating cooperative work. He found that temporal constraints and conflict have a profound influence on the coordination of work across actors and organizational boundaries. Similarly, trauma teams perform under severe time constraints; conflicts in time allocation and scheduling can have significant implications for patient care. Hindmarsh and Pilnick (2002) described how the passing of instruments by the nurses in the anesthetic room is timed and designed to anticipate how and when an instrument will be used, while Svensson et al. (2007) showed how surgeons coordinate their talk and hand gestures when operating on a patient to create and configure a shared workplace. The two studies provide an insight into the ways in which artifacts are used within the accomplishment of activities in surgical units and point to the importance of the concept of *awareness* in supporting collaboration. The concept of awareness is relevant to trauma teamwork. A thorough understanding of how trauma team members maintain situational awareness can inform the design of support technologies in this domain. Nonverbal communication, although rarely used for information exchange in trauma resuscitation, is important for the physical and mediated coordination of activities in the trauma bay. This thesis acknowledges the importance of awareness and nonverbal communication in trauma teamwork. However, an in-depth analysis of how these concepts interact with other features of trauma teamwork is not in the scope of this thesis.

Most studies of the role of information in collaborative medical work emphasize information needs and medical records and how these two can be brought together to solve problems (e.g., Bardram 1997; Gorman et al., 2000; Brown et al., 2004; Reddy & Dourish, 2002). Although informative, these studies have looked at teamwork over extended periods of time (hours to days), rather than on time-critical events such as trauma resuscitation. The complexity of the information needs of medical teams has been studied in several types of clinical settings, including intensive care units (ICU) (e.g., Reddy et al., 2002; Reddy & Jansen, 2008) and emergency departments (ED) (e.g., Reddy & Spence, 2008; Reddy & Spence, 2002). These studies have shown a high prevalence of information needs related to organizational factors in both the ICUs and

EDs, highlighting the importance of understanding the relationship between clinical and organizational aspects of work in these units. Their primary foci, however, have been on teams in small, rural hospitals with dynamics different than those of trauma teams. This thesis complements and extends this previous work to a different clinical setting. Although there are some similarities between trauma and other critical care units, there are also important differences that may limit the extension of previous findings to trauma resuscitation. First, the core members of the trauma team (attending surgeon, resident physicians, anesthesiologist, and orthopedic surgeons) are not dedicated only to trauma care and are called from their regular duties when trauma occurs. Second, information that guides decision making in trauma resuscitation becomes available during a very short time period and in a continuous data flow from sources inside and outside the hospital. Finally, trauma resuscitation requires managing patients based on emerging rather than existing information. In contrast to other settings, such as the ICU that often have the availability of detailed historic patient data, trauma resuscitation requires that care providers identify and treat potentially life-threatening injuries using information obtained during a much shorter period (about 30 minutes).

Studies of trauma teams

Several studies of trauma teams have examined work practices in trauma resuscitation. While they provide an important perspective, these studies are difficult to translate into technology requirements because they do not offer rich descriptions of the specific challenges faced by trauma teams. In addition, these studies have not attempted to model trauma teamwork, which was one of the goals of this thesis.

Studies of Sexton et al. (2000) and Thomas et al. (2006) revealed three fundamental components of trauma teamwork: *communication*, *management*, and *leadership*, with teams exhibiting information sharing and inquiry behaviors, vigilance, and workload management. The studies also found that the differential and hierarchical structure of the team might make some members in lower level roles reluctant to express their concerns, leading to communication omissions and errors. Within studies of leadership in trauma, the analytic focus primarily rests on leaders' adaptation to changing task demands (e.g., Xiao et al., 2004), the impact of leaders' location (local vs. remote) on team performance (e.g., Xiao et al., 2003), and leadership adaptations to various team structures (e.g., Klein et al., 2006). Faraj & Xiao's (2006) study showed two types of coordination practices as dominant in trauma teamwork: (1) expertise coordination practices (reliance on protocols, community of practice structuring, plug-and-play teaming and knowledge sharing), which are essential for managing distributed expertise, and (2) dialogic coordination practices (epistemic contestation, joint sense-making, cross-boundary intervention and protocol breaking), which are time-critical responses to novel events and ensure error-free operation. While their analysis remained at a high-level and was mostly qualitative, the findings offered important insights into trauma teamwork. This thesis used findings from these studies in developing a behavioral coding scheme to tag the collaborative activities of observed trauma teams (described in Chapter 3).

The studies of trauma teams described above represent only a few that are available in this area of research. Although relevant, these studies have several limitations. First, the majority of these studies were conducted by medical researchers who possess limited knowledge in human factors analysis. Second, the studies primarily relied on retrospective analysis of medical records, surveys, and subjective perceptions of the medical staff. Observational data was rarely used to corroborate the reported findings.

Finally, these studies failed to provide rich descriptions of the specific challenges faced by trauma teams that are necessary to achieve practical system designs. Given the dearth of studies in this area, weakness of the methods employed, and complexity of the problem, additional detailed studies are needed to gain deep understanding of the trauma resuscitation domain, which is essential to improving trauma care system.

2.3. Human Error and Errors in Trauma Resuscitation

Efforts to define and develop taxonomies of human error were motivated by incidents in nuclear power plants and airplane crashes in the 1970s and 1980s (Sheridan, 2003). Key to these efforts was the contribution of Rasmussen (1983), who developed an influential model of human cognitive information processing for studying complex human activities, termed the “skills-rules-knowledge” (SRK) framework. According to this framework, people solve problems at three cognitive levels: (1) skills, which are based on motor behavior; (2) expert rules, which are applicable to familiar problems; and, (3) knowledge, which is applicable to novel situations. Skills and rules operate quickly and effortlessly, while knowledge-based processing is slow and requires significant cognitive effort.

Most theoretical studies of human errors that followed were based on the SRK framework. The types of errors that people commit in problem solving are different for different operating modes. Reason (1990) classified errors based on the cognitive stages from the SRK framework. According to him, errors at the skills level include *slips* and *lapses*, which result from failures in the execution of an action sequence. Errors at the rules and knowledge levels are called *mistakes*, which are defined as deficiencies or failures in judgmental and inferential processes. Reason mainly attributed individual errors to cognitive underspecification, such as incomplete or ambiguous input information, fragmentary cues for memory retrieval, and incomplete or inaccurate knowledge. Although there was some progress in identifying errors after Reason's initial contributions (Reason, 2000), most of the work on human error has consisted in applying Reason's (1990) theoretical framework to specific domains, such as aviation (e.g., Helmreich et al., 1998; MacKay, 1999), healthcare (e.g., Donchin et al., 1995; Risser et al., 1999; Clarke et al., 2000; Gruen et al., 2006), and industrial and energy plant control (e.g., Woods & Cook, 2002).

One weakness of Reason's theoretical framework is that it only considers errors as they relate to individuals and does not consider errors that are unique to teamwork. Recently, there has been some effort in this area, including Reason's own efforts (Sasou & Reason, 1999; Trepess & Stockman, 1999). Team error is defined as a human error committed in the group processes, and the concept of team error is limited to mistakes and lapses. Mistakes and lapses occur in planning and thinking, and are more likely to be associated with group processes than action slips, which primarily emerge out of the execution processes. The existing taxonomies of team errors comprise two main categories: (1) the error-making process, and (2) the error-recovery process. The types of errors arising during the error-making process include (i) individual errors, which can be both independent (all information available to perpetrator is correct) and dependent (some part of information available to perpetrator is inappropriate, absent, or incorrect); and, (ii) shared errors, which can also be independent or dependent. Recovery errors include (iii) failure to detect occurrence of an error, (iv) failure to indicate that an error has occurred, and (v) failure to correct the errors. The existing taxonomies of teamwork errors are only theoretical and lack descriptions of real world situations that are needed to achieve practical system designs. The teamwork error classification scheme that resulted from the work described in this thesis differs in that it used real-world observations to identify errors unique to teamwork. Although limited to the trauma resuscitation domain, this novel teamwork error classification scheme could be applied to studying other safety, socio-technical systems.

There is a vast body of literature on medical errors, some of which specifically focuses on identifying errors in trauma resuscitation. Yet, relatively few studies have explored the relationships between human factors and errors in trauma care. For example, studies in health care, including trauma, have examined communication problems (e.g., Coiera et al., 2002; Lingard et al., 2004; Bergs et al, 2005). It has been shown that communication between trauma team members is poor during high intensity resuscitations. This body of work, however, has not considered how much of the errors can be attributed to communication failures and what the impact of worker specialization might be on error occurrences. This thesis is a step toward filling this gap. It explored whether or not relationships exist between errors and certain contextual aspects of teamwork in trauma care.

Error analysis in trauma resuscitation has so far employed two approaches. The first approach lacks a theoretical basis and applies an ad hoc scheme based on expert knowledge of the domain. Researchers have used the Advance Trauma Life Support (ATLS) guidelines, which prescribe the order of steps in patient evaluation (***A***irway, ***B***reathing, ***C***irculation, ***D***isability, and ***E***xposure), and defined errors in terms of how much an action complies or deviates from the protocol (Santora et al., 1996; Ritchie &

Cameron, 1999; Houshian et al., 2002; Luten, 2002; van Olden et al., 2003; Oakley et al., 2006). For example, Oakley et al. (2006) observed a delay in applying oxygen of more than five minutes in 67% of analyzed resuscitation events. This was considered an error in airway management because it deviated from the protocol, which allows five minutes to institute oxygen therapy.

The second approach is based on Reasons' (1990) theoretical framework for studying human errors, and considers the types of errors and their causes. Taxonomies of errors that emerged using this approach are "problem-centric" and focus on errors related to medical tasks and their effect on the patient. Clarke et al. (2000) classified errors during trauma resuscitation as: *error of commission* (wrong goal pursued), *error of omission* (required goal overlooked), and *error of selection* (goals addressed out of order). This taxonomy is static and does not consider errors as part of the process, i.e., at which step of the process they occur. While Clarke et al. (2000), examined all errors observed during trauma resuscitation regardless of their impact, Gruen et al. (2006) focused on errors that contributed to hospital deaths. They developed a framework that considered "where" in the process errors happen and classified them by cause as: *input errors* (incorrect input data leading to incorrect intention and action), *intention errors* (incorrect intention leading to incorrect action), and *execution errors* (correct intention but incorrect action). Gruen and colleagues judged errors as they related to the patient evaluation process, but viewed the team as an undivided system, rather than as a group of communicating individuals. While both taxonomies are useful for tracking the impact of errors, neither studied how team interaction affected error rates or how triggering events related to error causation. Their focus was on errors statistics, rather than on how errors might be prevented by information technology.

This thesis adopts a broad systems approach to error analysis to allow for detailed examination of contextual aspects that shape trauma teamwork, including the roles, work assignments, communication, and information needs of trauma team members. Resuscitation events were observed and videotaped, and then analyzed using a mixture of qualitative methods. Particular attention was paid to critical situations that resulted in inefficiencies and near-miss errors. Based on this analysis of critical situations in which errors occurred, a model of trauma teamwork was proposed and an error-classification scheme was derived to explain teamwork errors.

2.4. Computerized Decision Support for Collocated Teams

Research efforts toward understanding the intricacies of clinical care so far have not produced many decision support systems that are actually used in clinical settings and that effectively contribute to the quality and safety of care (Wears & Berg, 2005). It is acknowledged that clinical decision support systems can improve efficiency, lower costs and improve outcomes, but objective evaluations vary (Garg et al., 2005). Systems often operate based on a work model of managers and designers, rather than on a mental model of field workers. In particular, theories of managers and designers hold that clinical work is objective, rational, linear, single-minded, and localized in the head of clinicians. The real clinical world, however, looks quite different from the perspective of front-end workers: it is interpretive, multitasking, interruptive, collaborative, and distributed. Because of this mismatch between the models of healthcare work inscribed in decision support tools and the actual nature of clinical work, clinicians seldom use them to make real decisions (Wears & Berg, 2005).

Due to the importance and frequency of decision-making errors in trauma resuscitation, prior applications of technology in the trauma bay have mainly focused on providing computerized clinical decision support. An example is the TraumAid, an artificial intelligence system that uses expert rules and logical deduction to generate management goals for trauma resuscitation (Clarke et al., 2002). This system was designed using rules given by domain experts. When used in 40 actual resuscitations, physicians found the system helpful in 21 interactions (53%), in which it mainly reassured them of their own plans. A disadvantage of this system was the considerable time required for manual data entry and the inadequate display of recommended decisions (text output on a single computer monitor).

Xiao et al. (2001) and Xiao et al. (2007) developed and deployed a whiteboard in a Level 1 trauma center to examine its use and whether or not this intervention improved medical staff's general awareness of what is going on in the center. It appeared that the whiteboard was used mostly for scheduling operations after the patient was released from the trauma bay. Additionally, the whiteboard was placed outside the trauma bay, and as such, its use did not reveal much about trauma team coordination and collaboration *during* trauma resuscitation. Nevertheless, the results of this study showed that status boards support work that is distributed over people, time and space in multiple ways. The boards facilitate task tracking and management, resource planning and tracking, synchronous and asynchronous communication, problem solving and negotiation, and socialization and team building.

A number of potential technological solutions have been offered to support workflow, awareness, and information absorption in both collocated and distributed medical teams (Watson et al., 2004; Wilson et at., 2006; Wears et al., 2007). The ideas from these studies, such as shared and interactive displays for presenting information and unobtrusive tracking of co-workers will be considered in the discussion of potential technological solutions to support the work of trauma teams.

For example, Bardram et al. (2006) developed and implemented a system called AwareMedia to support spatial, temporal, and social awareness in an operation ward. The system supports spatial awareness by providing medical staff with awareness of: the kind of operation that is taking place; the level of activity or status of the operation; past, present, and future activities and events which may be relevant to them; and their colleagues, what they are doing and where they are. Similar solutions could be considered to help with information absorption during trauma resuscitation. Instead of supporting general awareness of “who is around” or “what is going on,” awareness technologies in trauma resuscitation could help maintain awareness about what information had been reported or what treatments had been given.

As seen from the above discussion, developing effective clinical decision-support systems has been challenging. While the goal is improved efficiency, lower costs and better outcomes, objective evaluations of pilot systems vary. Current systems are often built based on a work model of managers and designers that is less relevant to practicing clinicians. An in-depth study of teamwork in trauma resuscitation is thus needed to elicit design requirements that will lead to the development and deployment of useful and usable systems to support the work of medical teams.

2.5. Summary

Chapter 2 reviewed prior work relevant to the research problem addressed in this thesis. Studies from three research areas were examined to differentiate the novelty of the current work from the work done previously.

Previous studies of teamwork in both medical and non-medical domains have greatly deepened our understanding of collaboration in high-functioning teams, but have mostly focused on: a) collaboration between pairs and small groups rather than on collaboration in large, collocated teams; and b) the processes and work strategies that help the teams maintain failure resistant performance rather than on team failures and their causes. The work described in this thesis, with its detailed analysis of trauma teamwork, contributes to the existing body of research by providing new insights into the collaboration of larger groups (up to 15 professionals) in time-critical work settings. Most importantly, the current work examines situations in which trauma teams committed errors and identifies and explains potential causes of those errors.

Review of prior work on human error pointed to the existing taxonomies of teamwork errors. These taxonomies, however, are mostly theoretical and lack descriptions of real world situations that are needed to achieve practical system designs. The current work differs in that it proposes a novel, team error classification scheme that emerged based on real-world observations of teamwork in a highly dynamic and safety-critical environment.

Finally, efforts to develop information systems that support trauma teams have had limited success so far. Developing information tools to support teamwork in trauma resuscitation requires a better understanding of how trauma teams work. Prior studies of trauma resuscitation have independently examined leadership, communication, information behavior, medical errors and deployment of simple technological interventions, such as whiteboards. Although informative, these studies do not provide rich descriptions of trauma teamwork, which are necessary for successful systems design, development, and deployment. The current work fills in these gaps by providing both rich descriptions of trauma teamwork and the design requirements that computerized support must meet to support teamwork in a complex, socio-technical system such as a hospital.

Chapter 3

Research Questions and Research Framework

3.1. Chapter Overview

This chapter introduces the research questions that this study posits and describes the research and theoretical frameworks that were adopted to examine the complex system of trauma care. The chapter starts with a list of research questions, providing reasons for those research questions as well as what information is expected to be gained by addressing those questions. This is followed by a description of the research framework, which combines several distinct approaches for studying the trauma resuscitation domain: cognitive work analysis, the "skills-rules-knowledge" (SRK) framework, and a grounded theory approach. The chapter concludes with a review of transactive memory theory describing the rationale behind selecting this theoretical framework for the purposes of this research.

3.2. Research Questions

The staff in trauma centers are faced with solving complex problems under time pressure. Because patients and their injuries are unique, care cannot be routine. Despite this variation, there are principles that are known to improve care and efficiency such as the ATLS treatment protocol. Trauma teams sometimes make errors by deviating from these principles, but it is not known when and why these errors occur. Errors disrupt the flow of care, slow the speed and efficiency of the patient evaluation and may have cascading effects leading to poor patient outcome. Unlike team operations in other high-risk domains, trauma resuscitation is carried on without any information technology support. Also, because of the need for rapid diagnosis, the trauma bay lacks sophisticated technologies that aid medical procedures found in other hospital settings. Despite considerable efforts, few decision support systems have been developed that are actually used in clinical practice. Reasons include the challenge of automatically acquiring information from diverse sources in a dynamic environment, the difficulty of synthesizing acquired information into meaningful output and recommendations, worker resistance to unproven technology, and the stringent need for a fail-safe system. Perhaps the biggest reason of all is the lack of detailed studies of trauma resuscitation that provide rich descriptions and an in-depth analysis of work processes as a basis for system design, development, and deployment.

To help with understanding teamwork errors and their causes, this thesis performs a detailed study of the trauma resuscitation domain and provides rich descriptions of trauma teamwork in conjunction with answering the following research questions:

Research Question 1: What constitutes trauma teamwork?

Understanding the properties and limitations of trauma teamwork may reveal where and when in the process errors occur. An answer to this research question will provide insights into the work processes of trauma teams by uncovering the goals, tasks, and procedures during trauma resuscitation. Subtending questions associated with the first research questions are as follows:

1. What are the goals of trauma resuscitation?
2. What are the tasks associated with the goals of trauma resuscitation?
3. What are the roles and work assignments of each trauma team member?
4. How are procedures and tools used for achieving the goals of trauma resuscitation?

5. What kinds of artifacts support trauma teamwork?
6. What are the larger organizational factors that influence the work of trauma teams?

Research Question 2: What are the information needs of trauma teams?

Understanding information needs and how they change over the course of trauma resuscitation may reveal important properties and limitations of information exchange during trauma resuscitation. The insights gained by the analysis of information exchange will help with identifying team errors that may be caused by communication breakdowns, as well as with devising new approaches for more efficient management of information in the trauma bay. Subtending questions associated with the second research questions are as follows:

1. How do trauma team members fulfill their information needs?
2. How do information needs differ based on the role of each team member?
3. How do information needs change throughout the process?
4. What communication practices are used to exchange information?
5. How do communication practices affect the work of trauma teams?

Research Question 3: How do trauma teams make decisions?

Due to the importance and frequency of decision-making errors in trauma resuscitation, it is important to understand how trauma teams make decisions. An answer to this question may reveal the types of difficulties that trauma teams face when making decisions. This knowledge can then be used for modeling trauma teamwork and for devising new

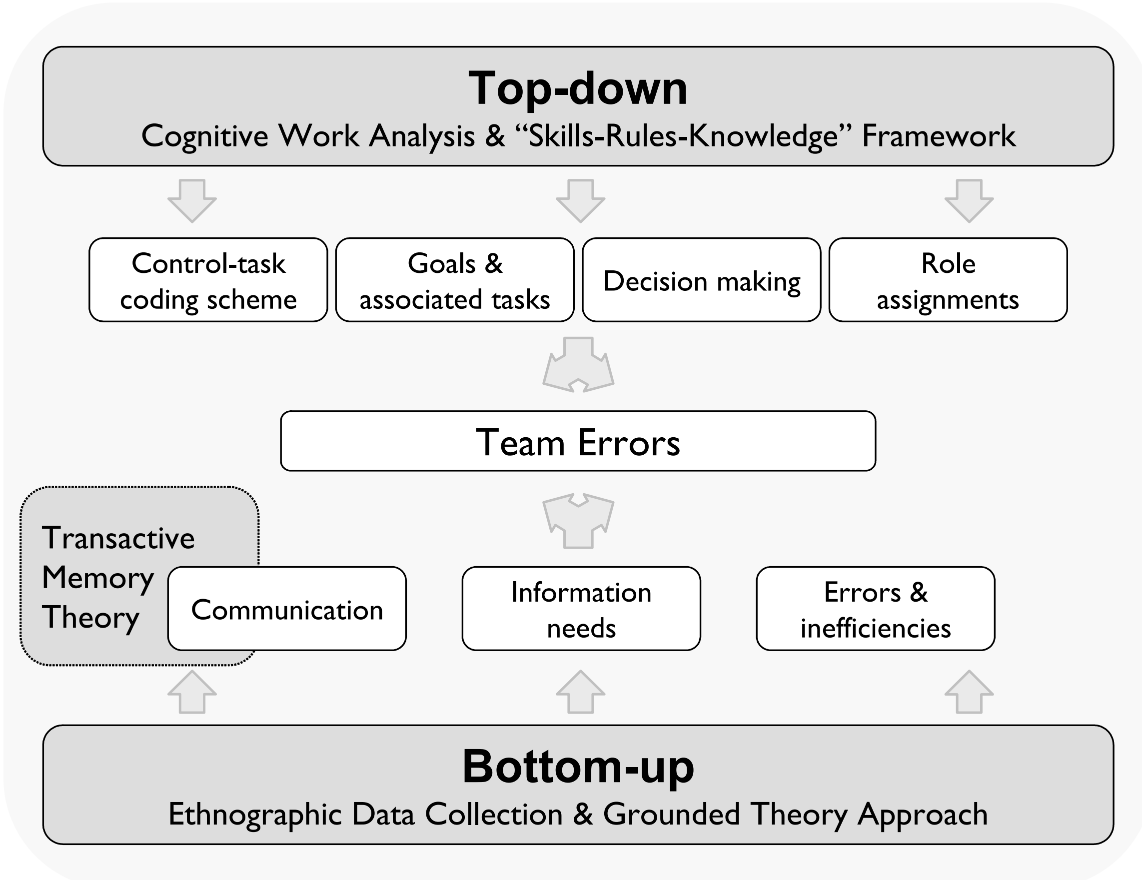


Figure 3-1: Summary of the research approach.

approaches to reducing errors through changes in procedures or the introduction of technology. Subtending questions associated with the third research questions include:

1. What information do trauma teams use to make decisions?
2. What strategies do trauma teams use to make decisions?
3. When in the process do trauma teams make decisions?

To answer the above research questions and understand such a complex, socio-technical system, a research framework that allows both quantifying and describing the behavior and work processes of trauma teams is needed. The following sections explain the multiple approaches this thesis adopts to uncover the subtleties of trauma teamwork, and identify and explain the causes of errors unique to teamwork.

3.3. Research Framework

This thesis uses both inductive (bottom-up) and deductive (top-down) approaches to stud the trauma resuscitation domain in order to identify team errors and their causes, answer the research questions, and enable a "thick description" of the work of trauma teams (Geertz, 1973) (see Figure 3-1).

3.3.1. Top-down approach

A top-down approach is driven by *cognitive systems engineering*, an emerging field that is concerned with the analysis, design and evaluation of complex socio-technical systems (Hollnagel & Woods, 2005). Two specific frameworks within cognitive systems engineering are applied to studying the trauma resuscitation domain: *cognitive work analysis* (CWA) (Vicente, 1999; Vicente 2002; Sanderson, 2003), and *skills-rules-knowledge framework*, also known as the SRK framework (Rasmussen, 1983).

Cognitive work analysis represents a framework for collecting and analyzing data about socio-technical systems such as nuclear power plants or air traffic control centers. It is an evolution of a range of techniques and frameworks that have been developed for analyzing complex human work. CWA focuses primarily on work analysis and serves as a means to derive implications for technology design (Vicente, 1999). CWA has been successfully applied in modeling several medical sub-domains, including the operating room (Hajdukiewicz et al., 2001), emergency ambulance dispatch (Chow & Vicente, 2002), and the design of monitoring interfaces for neonatal intensive care (Sharp & Helmicki, 1998). CWA is particularly useful for understanding highly complex socio-technical systems with multiple actors and constraints. For these reasons, this methodology is appropriate for an analysis of trauma teams' work.

In particular, the use of CWA approach in this thesis provided an answer to the first research question by enabling a thorough analysis of the goals, work practices, role assignments and tasks of trauma resuscitation teams. The basic techniques of CWA are similar to other human-computer interaction approaches for capturing data—interviews, observations, focus groups, surveys and document collection. This thesis uses observations, video recording, interviews, and focus groups.

In conjunction with the SRK framework (described in Section 2.3), CWA also served as a framework for developing a behavioral coding scheme for tagging collaborative activities of trauma team members in video recordings. Section 3.4 provides a detailed description of how CWA and SRK frameworks are used in this work.

3.3.2. Bottom-up approach

In contrast to a top-down approach, bottom-up work is data-driven: it applies a *grounded theory approach* (Glasser & Strauss, 1967) to data collected through a mixture of ethnographic methods, including observations, video recording, interviews, and focus groups. A grounded theory is one that is

> … derived from the data, systematically gathered and analyzed through the research process. In this method, data collection, analysis, and eventual theory stand in close relationship to one another. A researcher does not begin a project with a preconceived theory in mind… Rather, the researcher begins with an area of study and allows the theory to emerge from the data. (Strauss & Corbin, 1998, p. 12)

Because the main objective of this thesis was to produce rich descriptions of trauma teamwork and propose a set of assumptions about team errors and their causes, the grounded theory approach was selected as the most appropriate approach for accomplishing that objective. In addition to being used for identifying errors unique to trauma teamwork, the grounded theory approach provided answers to the second and third research questions. This approach was also used in developing a coding scheme for tagging communication and collaborative activities of trauma teams (described in the following section). A description of how the grounded theory approach was used for error analysis is presented in Chapter 4, in Data analysis section.

Each of the above-described approaches is unique and covers only a portion of the research presented in this thesis. However, when brought together, these approaches created a synergy that enabled both investigation and description of a complex, socio-technical system such as trauma resuscitation.

3.4. CWA, SRK and Grounded Theory Combined: Coding Scheme Development

Video recording is a valuable tool for collecting and recording behavioral data for detailed observational analysis and is now commonly used to analyze workflow and team communication in high-risk settings, including trauma resuscitation (Mackenzie et al., 2003). Although access to the research setting had been secured through collaboration with trauma surgeons at the Robert Wood Johnson University Hospital, obtaining the permission to videotape actual trauma resuscitations turned out to be challenging. To circumvent the risks involved in videotaping live resuscitations, such as patient privacy and medico-legal concerns, it was explicitly stated that a) this study does not focus on the patient, and thus, no personal patient data will be recorded, and b) any written records produced during the study will exclude resuscitation dates, times, and any personal or other information that could permit identification of a patient, a specific resuscitation, or a trauma team member. As a result, Institutional Review Board (IRB) approval was secured, but it required destruction of video recordings within 96 hours of the videotaping. This requirement posed several constraints on data collection and analysis. First, to enable a thorough analysis of collaborative activities after the video record was deleted, a detailed transcript needed to be produced for each videotaped resuscitation. Second, transcripts needed to be anonymized, and any identifiable information had to be removed. Finally, transcripts needed to capture as much information as possible to enable a detailed analysis of the goals, work practices, and tasks of the resuscitation team. These constraints mandated the development of a method for formally representing and analyzing the collaborative processes during trauma resuscitation without relying on the actual video recordings.

To this end, cognitive work analysis provided the basis for developing a coding scheme for tagging collaborative activities of trauma team members in video recordings. More specifically, this study applied only the second phase of CWA, known as *control task analysis* (Vicente, 1999). Control task analysis allows identification of the requirements associated with known, recurring events or situations and, mostly, describes what needs to be done. The use of control task analysis for the purposes of developing a coding scheme was justified by the fact that the trauma team has a clear subject of work (the patient), with observable parameters that are used to specify the goals of the team's work and their success criteria. In addition, current medical care defines a set of actions and treatments that are used to bring the team towards their goals of optimal patient outcome. The following paragraphs explain how control task analysis was used for the development of a coding scheme, first by defining key concepts and then by providing a description of the analysis.

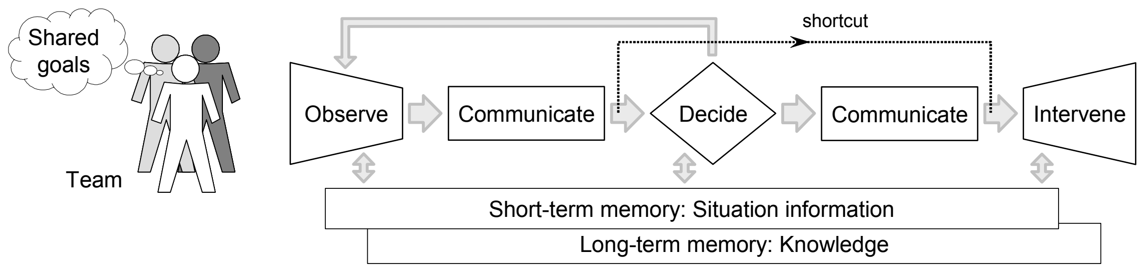


Figure 3-2: Control and communication tasks in team-based goal achievement.

A *goal* is defined as a state that a worker 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 worker may provide supplementary oxygen to the patient. A *procedure* is a sequence of actions carried out to accomplish a task. For example, the task of providing oxygen is achieved by connecting a facemask to an oxygen outlet, placing the mask over the patient's face and opening a valve.

The key categories of control tasks (Vicente, 1999) involved in achieving goals are (Figure 3-2):

1. *Observations*: a set of activities performed by an actor to measure the current value of a state variable
2. *Decisions*: a comparison of the current and goal states, and devising methods to reach the goal state by
    a. additional observations to determine the system state more accurately
    b. interventions that modify the values of the state variables to more closely approach the goal state
    c. no additional actions when the current state is sufficiently close to the goal state

Table 3-1: Coding scheme for categorizing control tasks and communication in trauma resuscitation.

MAIN CATEGORIES		SUBCATEGORIES	CODE
Information acquisition and retrieval	**Observing**	Physical examination (auscultation, palpation)	EXM
		Manual measurement	MM
		Simple sensing: sight, sound, touch, time	SEN
		Instrument reading	IR
	Memory recall & info retrieval	Knowledge recall	LTM
		Situation recall	STM
		Info retrieval from artifacts (trauma flowsheet, notes, x-ray workstation…)	MEXT
Communication & Intervention	**Verbal communication**	Directives (Task assignment / Instruction / Command)	DIR
		Report (about patient status or team member activity)	RP
		Inquiry / Request for information	Q
		Response to an inquiry or request for information	RS
		Clarification (Request for retransmission of information)	CL
		Relay	RLY
		Acknowledgement	ACK
		Summons	SM
	Nonverbal procedures	Therapeutic intervention / Treatment	INT
		Setting-up instrument/equipment	SET
		Recording information (e.g., on a trauma flowsheet)	RC
		Handing / Receiving an object	HRO
Decision-making	**Skill-based behaviors**	Task coordination	TC
	Rule-based behaviors	Solo decision making	SDM
		Strategic planning	SP
		Judgment: Approval vs. Disapproval vs. Praising	JU (A/D/P)
		Takeover / Handover of leadership role	TO
	Knowledge-based behaviors	Group decision making	GDM
		Coaching / Educating	ED

3. *Interventions*: a set of activities performed by an actor to change the current value of a state variable.

These high-level categories of control tasks in Figure 3-2 provided the overarching framework for developing a coding scheme for categorizing team activities during trauma resuscitation (Table 3-1).

In addition to the main control task categories, which came from the control task analysis, the model in Figure 3-2 contains two categories that emerged from pilot observations and the analysis of two simulated trauma resuscitations: *communication* category and *memory recall and information retrieval* category. The *communication* category refers to information exchange between trauma team members during resuscitation. As observed in the two simulations, communication was mostly in the service of other tasks and was usually preceded and followed by non-communication tasks. In the context of dynamic, high-risk teamwork, communication only indirectly contributes to the goal achievement and generally is considered an overhead that should be kept at a minimum. Thus, although a full-fledged task, communication in trauma resuscitation mostly serves as a *link* between other types of control tasks (observation / decision / intervention). In communication, coding units are typically small intervals of conversation (Weiss et al., 1973), speaker turns (Krokoff et al., 1986) and thought turns, or semantic turns, in which a change in semantical content indicates a different message requiring a code (Sillars, 1986). This study adopts speaker turn-taking as the main unit of communication analysis.

Observation data also indicated that team members rely on their memory and various artifacts (e.g., trauma flowsheet, handwritten notes) to retrieve situation-specific and medical information when performing their tasks. To account for these activities, the category *memory recall & information retrieval* was added.

The “pipeline” model in Figure 3-2 is a model of how teams perform complex tasks. When applied to trauma resuscitation, it can be viewed as a model of the trauma resuscitation process: the boxes stand for different control tasks performed by team members and the arrows represent a “logically-leads-to” relationship. In short, the process starts with *observations* where various team members collect patient information from the environment. Acquired information is then *communicated* to the team leader and the rest of the team. The team leader uses this information for *decision making*; if more information is needed, the team can go back to observation tasks. Once a diagnosis is reached and a decision is made about a treatment, *intervention* tasks are assigned through communication exchanges. The model also indicates a shortcut where some observations are directly pre-wired to interventions, thus bypassing decision making for routine activities (Vicente, 1999).

Each category in this model is further divided into subcategories (Table 3-1). These subcategories are partially based on previous work (e.g., Thomas et al., 2006), as well as on observations and analysis of the two simulated resuscitations. Pilot observations and the recording of two simulated trauma resuscitations took place in April and May of 2006. Simulated resuscitations were the only videotapes that did not have to be discarded and, thus, provided an ideal resource for developing a coding scheme. The development of the coding scheme was performed in accordance with a grounded theory approach. The initial analysis resulted in an exhaustive list of activities that trauma teams perform during trauma resuscitation. This list was then verified against additional observations. As a result, some of the initial subcategories were eliminated or grouped into more general ones. Sections 3.4.1 through 3.4.3 describe the process of developing the coding scheme and explain each category and subcategory in detail along with representative examples.

3.4.1. Information acquisition and retrieval

This high-level category represents a set of activities performed by an actor (care provider) to *acquire* and *measure* the current value of a state variable (i.e., patient status). It is further divided into two major categories: observation, and memory and information retrieval. Initially, each of these two categories represented a separate, high-level category. However, after additional observations indicated that team members gather patient information not only via observational tasks, but also by consulting various paper artifacts and recalling information from memory, the two categories were grouped into one, high-level category.

Observation

Trauma team members acquire patient information by performing various assessment, monitoring and measurement tasks. Four subcategories, or specific tasks that support information gathering in the trauma bay, were identified in both simulations and were later verified against additional observations: physical examination of the patient (e.g., palpation, auscultation or listening to breath sounds using a stethoscope), monitoring patient status by reading values from various instruments (e.g., reading blood pressure from a vital signs monitor), assessing patient's status using various tools (e.g., taking temperature by using a thermometer), or gathering information via simple sensing. The physical examination subcategory was initially named "assessment / diagnosis" task. This name, however, introduced ambiguity as more data was collected. For example, assessment can refer to any type of exam including assessments based on a medical chart or a verbal report given by another care provider. To account for exams that involved interaction with the patient and immediate interpretation of the results, "assessment / diagnosis" task was renamed "physical examination." By doing so, this category enabled identifying and tracking team members that are directly involved in hands-on patient evaluation. The other tasks in this category remained unchanged. The following paragraphs provide additional detail about observation tasks and list representative examples.

Physical Examination: In this task, a team member examines patient status, and immediately interprets the results. The physical examination is performed using a specific instrument (e.g., a stethoscope), or by simple palpation. This type of behavior is typically followed by a *Report*. A physical examination is different from a *Manual Measurement* scenario (which also includes the use of an instrument) because it involves an interpretation of the measurement, which in turn requires expert knowledge. A physical examination is also different from *Sensing* because of interpretation; any team member can do sensing, whereas, physical examination is typically done by a physician (e.g., residents, attending physicians, orthopedic surgeons, etc.). Table 3-2 shows examples of physical examinations (examples italicized).

Table 3-2: Examples of Physical Examination.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(*listens to breath sounds*, talks to	TEAM)	I hear something on the right.
Junior resident	(*palpates patient's feet*, talks to	TEAM)	He's got distal pulses!
Junior resident	(*performs rectal exam*)		

Manual Measurement: In this task, a team member acquires information about patient status using a manual tool or an instrument such as a manually inflated blood pressure cuff. This task is different from *Instrument Reading* because the information is obtained manually, not automatically (or electronically). Table 3-3 shows examples of manual measurements (examples italicized).

Table 3-3: Examples of Manual Measurement.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Junior resident	(*examines patient's eyes with pen light*)		
Junior resident	(talks to	Recorder)	Pupils 4 mm, non-reactive.
Technician	(*measures temperature with thermometer*)		
Technician	(talks to	Recorder)	(Name), temp is 94.3

Sensing by sight, sound, touch, time: In this task, a team member acts based on his or her immediate observations in the trauma bay. A team member collects information via simple sensing using sight, sounds, touch and awareness of elapsed time. Table 3-4 shows an example of sensing (example italicized).

Table 3-4: Example of Sensing.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	TEAM)	Chest tube in?
Team leader	(*looks at inserted chest tube*)	TEAM)	Excellent, great! Connect to pleural bag.

Instrument Reading: In this task, a team member acquires information visually by looking either at the vital signs monitor or at other electronic instruments in the trauma bay. Table 3-5 shows examples of instrument readings (examples italicized).

Table 3-5: Examples of Instrument Reading.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Primary nurse	(*looks at the monitor*, talks to	Recorder)	(Name), he's got heart rate 110, 19 sat.
Team leader	(*at the x-ray workstation, examines x-ray images*)		

Memory recall and information retrieval from artifacts

As mentioned above, pilot observations indicated that trauma team members rely on their memory and various paper artifacts to retrieve situation-specific and medical information while performing their tasks. For example, in the middle of Simulation 1, the attending physician inquired about the mechanism of injury. The team leader remembered the initial report given by the emergency medical services (EMS) paramedics and provided a brief summary. The attending physician, however, wanted to know the details. Upon hearing this new request, the recorder referred to the trauma flowsheet and read the entire EMS report to the attending physician. Similar instances were later observed in other resuscitations. To account for these activities, the memory recall and information retrieval category includes three subcategories: knowledge recall (e.g., retrieving medical information from knowledge), situation recall (e.g., retrieving situation-specific information from short-term memory), and information retrieval from artifacts (e.g., handwritten notes or trauma flowsheet). This category is important because it helps with identifying information sources, as well as with understanding the documentation process and use of artifacts. The following paragraphs provide additional detail about memory recall and information retrieval subcategories and list representative examples.

Knowledge Recall: In this task, a team member uses his or her knowledge as a source of information when responding to questions and other requests from the team. In the example below (Table 3-6), the EMS paramedic responds to a team leader's question about administered medications en route. The paramedic is using his knowledge about the standard package of emergency medications, known as RSI (example italicized).

Table 3-6: Example of Knowledge Recall.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	EMS)	RSI... that can be ah…
EMS paramedic	(talks to	Team leader)	*Yeah, he got standard RSI, so he got succs, lidocaine, etomidate, vecoronium.*

Situation Recall: In this task, a team member uses his or her "short-term memory" as a source of information when responding to questions and other requests from team members. In the example below (Table 3-7), the team leader is answering the attending physician's question about the mechanism of injury based on what he remembered from EMS paramedic's report (example italicized).

Table 3-7: Example of Situation Recall.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Attending physician	(talks to	Team leader)	What's… what's the story here?
Team leader	(talks to	Attending physician)	*MVA.*
Attending physician	(talks to	Team leader)	That's it? MVA, nothing else?

Information Retrieval from Artifacts: In this task, a team member (usually a nurse recorder or EMS paramedic) uses artifacts such as a trauma flowsheet, notes, or other patient records as a source of information. In the example below (Table 3-8), the nurse recorder provides a summarized story about the accident by referring to the trauma flowsheet (example italicized).

Table 3-8: Example of Information Retrieval from Artifacts.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Attending physician	(talks to	Primary nurse)	What's the story?
Primary nurse	(talks to	Attending physician)	He hit a car…
Recorder	*(reads from TAFS,* talks to	Attending physician)	Restrained driver who's driving from police, hit a car, airbags deployed, restrained driver.

3.4.2. Communication and intervention

This high-level category represents a set of activities performed by an actor (care provider) in order to *exchange* and *share* information that relates to the patient status, assessment, and planned treatment of the patient. It is further divided into two major categories: *verbal communication*, and *nonverbal procedures* (Table 3-1). The reader will notice that the intervention category, one of the main control tasks adopted from the control task analysis, is now part of the nonverbal procedures category. There are two reasons for this decision. First, intervention is a procedure, an embodied action that is also communicating but is silent. Intervention may be preceded or followed by a communicative action, such as a clarification or report, but is generally nonverbal in nature. Second, through additional observations, several new activities emerged that did not fit into any of the control task categories. These included instrumentation setup, recording information, and handing or receiving an object. Initially, these activities were listed under "other" category. The list of tasks, however, was getting long and the coding scheme suddenly became cumbersome to use. There was a need to reconsider the "other" subcategories and regroup the initial ones. Similar to intervention, activities such as instrumentation setup or recording information are also communicative but silent. Thus, a decision was made to group all nonverbal, communicative procedures together and place them under the communication category.

Verbal communication

Verbal communication is critical in trauma resuscitation because of the hands- and eyes-busy nature of the work. Exchange and sharing of information about the patient is primarily verbal, which is why the verbal communication category is included in the coding scheme. The verbal communication category enabled the identification and an analysis of communication exchanges in the trauma bay. This category also helped with identifying the most common information seekers and providers (i.e., those who asked questions or provided responses), inefficiencies in communication (e.g., implied by the number of clarifications or repeated requests for information), and other features.

The initial set of verbal communication subcategories included two behaviors identified by Thomas et al. (2006): inquiry and assertion. Inquiries were also observed in two simulated resuscitations and were later verified against additional observations. Thus, this subcategory remained in the final version of the coding scheme. The assertion sub-category appeared to be ambiguous. Thomas et al. (2006) defined assertion as "an individual provider's opinion (through questions or statements of opinion) during critical times" (p. 164). As such, assertion does not have a communicative function, but rather a relational- or meta-dimension that shows how the information it carries factors into a larger context (J. D. Robinson, personal communication, January 31, 2008). For example, a communicative action such as a response can be judgmental. Judgment, then, is not a communicative action; it is a meta-dimensional category that shows how the content of that specific response factors into a decision-making process. Because the goal of the verbal communication category was to identify communicative actions that characterize the majority of communication exchanges during trauma resuscitation, all subcategories that had meta-dimensional component were either removed from the coding scheme because they were ambiguous (e.g., assertion) or were moved into the decision-making category (e.g., task coordination).

In addition to inquiries, the initial set of verbal communication subcategories included reports, responses, clarifications, relays, and acknowledgment. These sub-categories emerged from observations and simulated resuscitations, and were later verified against additional observations. The subcategory “directives” was added to verbal communication category later in the process. This subcategory was initially named “task assignment / instruction / command” and was placed under the decision-making category, denoting leadership. Revisiting observational notes and simulation transcripts suggested that task assignments, instructions and commands have the same communicative function, i.e., they all trigger an action. For example, when an anesthesiologist uttered, “*I'll have to call the backup help here*” in one of the simulations, the utterance prompted a nurse to pick up a phone and call the anesthesiology department. It was suggested that these and similar utterances be coded as directives (J. D. Robinson, personal communication, January 31, 2008). As a result, the “task assignment / instruction / command” subcategory was renamed “directives” and grouped together with other verbal communication subcategories.

Finally, as data collection proceeded, new communicative actions started to emerge in the transcripts that did not fit into any of the existing verbal communication subcategories. For example, it was noticed that trauma team members often call each other by first names to get each other's attention, e.g., "*Hey John!*" Or, team members sometimes announce their next steps, e.g., "*I am taking the blood now!*" Or, they ask about their schedules and task assignments, e.g., "*Do you need anything else from me?*" Or, they ask for an instrument, e.g., "*Can I borrow your stethoscope?*" Careful examination of these communicative actions revealed that their primary function is either to report (e.g., the next step a team member is taking), or to inquire (e.g., about one's task assignment or an instrument). Rather than adding new subcategories such as "announcements" or "requests for instruments," the decision was made to first determine the communicative function of these utterances and then code them accordingly, i.e., as reports or questions. The only new subcategory that was added was "summons" to account for cases when team members call each other by first names to get attention.

The final verbal communication category includes eight subcategories, all of which are mutually exclusive: directives (e.g., assigning a task), inquiries or information requests (e.g., inquiring about the latest blood pressure), responses, reports (e.g., reporting about the latest vital signs or patient history), clarifications (e.g., requesting re-transmission of information in case it was missed or understood incorrectly), message relays, summons, and acknowledgments. The following paragraphs provide additional detail about each subcategory and list representative examples.

Directives: In this form of communication exchange, one team member is leading the conversation and is telling the other team members what actions to perform.

Typically, this is done by the team leader. However, as leadership may be shared, other team members may engage in this type of behavior as well. This type of communication is different from a *Strategic Planning* scenario because it is followed by an immediate action, whereas actions requested by strategic planning can take place later in resuscitation. In the examples below (Table 3-9), the attending physician gives an order to the primary nurse to administer fluids, and the team leader requests that someone in the team repeat the accident story (example statements are italicized).

Table 3-9: Examples of Directives.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Attending physician	(talks to	TEAM)	Do we have access to IV fluid?
Primary nurse	(talks to	Attending physician)	We have 18 and 16 in his (right) arm.
Attending physician	(talks to	Primary nurse)	*Go ahead and give him a liter.*
Team leader	(talks to	TEAM)	*Can somebody please repeat the story!*

Report: In this form of communication exchange, a team member shares critical patient information about the patient status. These are self-initiated reports about vital signs, mechanisms of injury, and results from primary and secondary surveys. Reports also include team members' announcements about their actions (e.g., "*I am putting a chest tube*" or "*I am leaving, call me if you need me*"). When reporting, team members typically raise their voices so that others can hear them. This type of communication is different from a *Response* scenario because provided information is not requested, but self-initiated. Table 3-10 shows examples of reports (examples italicized).

Table 3-10: Examples of Reports.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	TEAM)	Roll him towards me.
Technician	(looks at the monitor, talks to	TEAM)	*Blood pressure is 98 over 56, and heart rate is 111.*
Team leader	(examines breath sounds, talks to	TEAM)	*I've got clear breath sounds!*

Inquiry: In this form of communication exchange, a team member makes an explicit information request about a patient, a procedure, or a team member. Inquiry is usually triggered by an information need. In short, team members question each other about patient's status, their assessments, and treatment plans. Table 3-11 shows examples of inquiries (examples italicized).

Table 3-11: Examples of Inquiries.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	EMS paramedics)	*When was the last dose of Epi and Atropine?.*
Team leader	(talks to	Technician)	*We got a pulse on him?*
Technician	(talks to	Team leader)	Yes.
Team leader	(talks to	TEAM)	*Do we have x-ray here?*
Attending physician	(talks to	TEAM)	*What's the blood pressure?*
Technician	(looks at the monitor, talks to	Attending physician)	Blood pressure is 98/56, heart rate is 109.

Response: In this form of communication exchange, a team member gives an explicit answer to an inquiry or information request. Table 3-12 shows examples of responses (examples italicized).

Table 3-12: Examples of Responses.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(palpates patient's abdomen, talks to		
Team leader	(talks to	TEAM)	We got a pulse on him?
Technician	(talks to	Team leader)	*Yes.*
Attending physician	(talks to	TEAM)	What's the blood pressure?
Technician	(looks at the monitor, talks to	Attending physician)	*Blood pressure is 98/56, heart rate is 109.*

Clarification (Request for re-transmission of information): In this form of communication exchange, a team member either misses or misunderstands information provided by another team member. A team member then repeats misunderstood information or asks for it to be repeated. This type of communication is different from an *Inquiry* scenario because it is triggered by a team member's report about his or her current activity or the patient's status. In most cases, there is little or no feedback after clarification. In the example below (Table 3-13), the nurse recorder clarifies information by repeating what she heard from the orthopedist's response (example italicized).

Table 3-13: Example of Clarification.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Recorder	(talks to	Ortho)	Are you ortho?
Ortho	(talks to	Recorder)	Yes.
Recorder	(talks to	Ortho)	Name?
Ortho	(talks to	Recorder)	Wilson.
Recorder	(talks to	Ortho)	*Wilson?*
Ortho	(talks to	Recorder)	Yeah.

Relay: In this form of communication exchange, a team member transfers information that she or he heard to another team member. Table 3-14 shows an example of message relay (example italicized).

Table 3-14: Example of Relay.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	TEAM)	Right eye abrasion!
Junior resident	(approaches recorder, talks to	Recorder)	You got stickers?
Ortho	(enters room)		
Primary nurse	(talks to	Recorder)	*Lac to the... above right eye!*

Acknowledgment: In this form of communication exchange, a team member confirms that the information has been heard and understood. This is often done through a simple repeat of the request or remarks such as "okay" and "yeah." Team members also acknowledge the help of their colleagues by thanking them for fetching an object or reporting information. In the examples below (Table 3-15), the recorder acknowledges the receipt of information about patient injury; junior resident acknowledges help from another team member who fetched an examination tool for her (examples italicized).

Table 3-15: Examples of Acknowledgment.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(points to right leg, talks to	TEAM)	Abrasion on the right side, you got that already?
Recorder	(talks to	Team leader)	*Yeah, abrasion, got that!*
Junior resident	(talks to	TEAM)	Can someone get me some jelly?
Technician	(fetches jelly, gives to	Junior resident)	
Junior resident	(talks to	Technician)	*Thank you.*

Summons: In this form of communication exchange, a team member calls another team member by name to get his or her attention. Table 3-16 shows examples of summons (examples italicized).

Table 3-16: Examples of Summons.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Technician	(talks to	Recorder)	*(Name), temp is 94.3!*
Recorder	(talks to	Technician)	What?
Technician	(talks to	Recorder)	94.3.
Primary nurse	(talks to	Respiratory therapist)	*(Name), can you get me the IV toolkit.*

Nonverbal procedures

In addition to using verbal communication, trauma team members exchange information through a set of nonverbal procedures such as interventions, instrumentation setup, information recording and handing or receiving objects. As briefly explained above, *intervention* represents a control task identified as one of the key control task categories. For the purposes of simplifying the coding scheme so that it can be effectively used, the interventions category was grouped with other nonverbal procedures. The following paragraphs provide additional detail about each subcategory and list representative examples.

Therapeutic Intervention or Treatment: In this control task, a team member performs medical intervention, such as administering fluids or medications, inserting an endotracheal tube, or inserting a chest tube. Intervention is an action intended to help the patient. Interventions can be brief or lengthy. Brief interventions last for a short time period and are presented in a single line in the transcript. Lengthy interventions last for a longer period of time (e.g., couple of minutes) and can run through several lines in the transcript. Table 3-17 shows examples of both short and lengthy medical interventions (examples italicized).

Table 3-17: Examples of Intervention.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Technician	(*covers PTN with blanket*)		
Primary nurse	(*administers etomidate via IV*)		
Primary nurse	*(administers tetanus)*		
Team leader	*(starts intubation)*		
…	…	…	…
Team leader	*(finishes intubation)*		

Setting-up Instrument, Equipment, or Patient: In this action, a team member is setting up an instrument for a medical task. This scenario also includes adjusting the instrument, fetching equipment or medications and other preparatory activities. In some cases team members are also setting up the patient, e.g., they cut the clothes off the patient to enable a thorough examination. Some types of setups can also run for several minutes (e.g., setting up the x-ray machine for taking x-ray images). Table 3-18 shows examples of setup actions (examples italicized).

Table 3-18: Examples of Instrument, Equipment, or Patient Setup.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Technician	(*prepares EKG leads*)		
Primary nurse	(*cuts the patient clothes off*)		
Attending physician	(*adjusts IV lines around patient's left arm*)		
Team leader	(*prepares cervical collar*)		

Recording Information: In this action, a team member records information using pen and paper. Information is typically recorded on a paper-based trauma flowsheet, physicians' progress notes, scraps of paper (e.g., EMS' notes) and other forms (e.g., a form for blood work). Table 3-19 shows examples of recording (examples italicized).

Table 3-19: Examples of Information Recording.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Recorder	(*writes patient's name down on a flowsheet*)		
Pharmacist	(*approaches recorder's desk, writes something down on a flowsheet*)		

Handing or Receiving an Object: In this action, a team member hands or receives an object (e.g., instrument, paper, medication, equipment, etc.) from another team member. Table 3-20 shows examples of this collaborative action (examples italicized).

Table 3-20: Examples of Object Handing or Receiving

ACTOR	ACTION	SUBJECT	COMMUNICATION
Technician	(*hands automatic BP cuff to*	Primary nurse)	
Primary nurse	(*brings blood samples and hands them to*	Recorder)	
Orthopedist	(*passes x-ray plate to*	X-ray Tech)	

3.4.3. Decision making

Decision making is an essential aspect of trauma teamwork. Understanding the decision-making process and its limitations will help uncover inefficiencies and teamwork errors in trauma care. Previous research has shown that decision making under time pressure usually relies on an application of expert rules and the recognition of familiar scenarios (e.g., Klein et al., 1993; Kirlik et al., 1996). To study the decision-making process, this thesis adopts Rasmussen's (1983) "skills-rules-knowledge" (SRK) framework (described in Chapter 2). Following Hutchins's notion of *distributed cognition* (Hutchins, 1995), a trauma team can be viewed as a cognitive system or a "team mind." While it cannot be observed directly whether a single mind uses rule-based or knowledge-based behaviors, this can be done for the team mind. The main objective of this component in the coding scheme is to distinguish skills/rules/knowledge behaviors from the team-mind perspective. To that end, decision making as a high-level category consists of three subcategories that correspond to Rasmussen's "skills-rules-knowledge" (SRK) framework: skill-based behaviors, rule-based behaviors, and knowledge-based behaviors.

Preliminary observations and discussions with trauma surgeons and residents indicated that trauma team members evaluate the patient by following the rules prescribed by the ATLS protocol. Most commonly observed manifestations of decision making included announcements of future treatments, e.g., "*Drop another liter of fluid, give him blood, but he'll probably need to go to the OR.*" This type of action was named "strategic planning" to denote the development of plans for subsequent patient care. Often times, the team leader simply started a treatment without any announcement or discussion. Activities such as these were named "solo decision making" to denote a decision that was made without any deliberation with other team members. Strategic planning and solo decision making can be viewed as rule-based behaviors because the decision maker follows the rules prescribed by the ATLS protocol. Because execution of the rules typically involves the collaboration of several team members, rule-based behaviors appear to be the most relevant for studying teamwork errors. Additionally, team members sometimes deliberate about alternative courses of action, thus participating in a knowledge-based behavior. These group discussions were named "group decision making" to denote decisions that were made by more than one team member. Finally, patient evaluation often requires a coordination of tasks performed by various team members. Examples of these tasks include a patient transfer from one stretcher to another, a patient log roll, or intubation, which requires coordination among the anesthesiologist and respiratory therapist. The activity of several team members coordinating their motor behaviors is considered a skill-based behavior and is coded as "task coordination." The following sections provide additional detail about each decision-making category and subcategories, and list representative examples.

Skill-based behaviors

Skill-based behaviors during trauma resuscitation are frequent and mostly applied individually, rarely collaboratively. Some collaborative skill-based behaviors include team coordination during patient log roll, or patient transfer from an emergency stretcher to a trauma gurney. Task coordination was identified as the only activity in which team members apply skill-based behaviors.

Task Coordination: In this collaborative activity, a team member coordinates several other team members as they are accomplishing a task. Table 3-21 shows examples of task coordination (examples italicized).

Table 3-21: Examples of Task Coordination.

ACTOR	ACTION	SUBJECT	COMMUNICATION
EMS paramedics	(talks to	EMS2, EMS3)	*Ready? One, two, three...*
Team leader	(talks to	Nurse, Technician)	*One, two and three... let's go back slowly.*
Primary nurse	(talks to	Junior resident)	*You wanna put the Foley in or you want me to do it?*

Rule-based behaviors

Trauma teams rely primarily on rapid, rule-based decision-making, in which expert rules are applied to familiar problems. This type of decision making is reflected in members' announcements (e.g., "*I am putting a chest tube*") or preparations for a task (e.g., a protocol-driven decision is to start measuring blood pressure upon patient's arrival to the trauma bay). Actions in this subcategory include solo decision making, strategic planning, judgment (i.e., judging a decision) and takeover (i.e., gaining control over the problem solution). Solo decision making and strategic planning subcategories emerged through observation and discussions with trauma surgeons and residents. Judgment and takeover subcategories came from the Klein et al. (2006) study of leadership in trauma resuscitation.

Solo Decision Making: In this action, a team member makes a decision on his own regarding a procedure or intervention. Solo decision making is reflected in an actor's announcement about his or her next step. Also, team members silently decide to do something, and this is reflected in their preparation for a task. In the examples below (Table 3-22), the team leader decides to give morphine to the patient. This decision is reflected in his question to the team. Table 3-22 also shows the technician who silently decides to put EKG leads on the patient for a cardio exam; this is a protocol driven decision and there is no need to have an order for it or to announce it to the whole team (example italicized).

Table 3-22: Examples of Solo Decision Making.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	Pharmacist)	*Can we give him some morphine? Do we have morphine on the board?*
Technician	(*prepares to put on EKG leads*)		

Strategic Planning: In this action, a team member conveys the overall plan or strategy for treating the patient, prioritizing possible interventions and revising the treatment plan as new information becomes available. Table 3-23 shows an example of strategic planning (example italicized).

Table 3-23: Example of Strategic Planning.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Primary nurse	(talks to	TEAM)	Heart rate 128, sat 78
Team leader	(talks to	TEAM)	*Let's get him intubated, then upstairs.*

Judgment: Approval/Agreement: In this action, a team member provides the directions for performing an action and receives confirmatory feedback from another team member, that is, another team member expresses his agreement with the proposed action. Approval typically follows a *Directives* or *Strategic planning* scenario. Table 3-24 shows an example of approval (example italicized).

Table 3-24: Example of Approval.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	Attending physician)	Can we do FAST?
Attending physician	(talks to	Team leader)	Let's do FAST.
Team leader	(talks to	Attending physician)	We do FAST?
Attending physician	(talks to	Team leader)	*Let's do FAST.*

Judgment: Disapproval/Disagreement: In this action, a team member provides the directions for performing an action and receives negative feedback from another team member, that is, another team member expresses his disagreement with the proposed action. Similarly to approval, disapproval typically follows a *Directives* or *Strategic planning* scenarios. Table 3-25 shows an example of disapproval (example italicized).

Table 3-25: Example of Disapproval.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Junior resident	(talks to	Team leader)	Let's roll him.
Team leader	(talks to	Junior resident)	*You got to have blood pressure before you roll him!*

Judgment: Praising (effective performance): In this action, a team member (typically a team leader or attending physician) expresses satisfaction with members of the team when they do their job well. Table 3-26 shows an example of praising (example italicized).

Table 3-26: Example of Praising.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Team leader	(talks to	TEAM)	Chest tube in?
Junior resident	(talks to	Team leader	Yes.
Team leader	(talks to	TEAM)	*Excellent, great!* Connect to pleural bag.
Primary nurse	(talks to	Technician)	Connect it to pleural bag.

Takeover/Handover of Leadership Role: Previous work (e.g., Klein et al., 2006) has provided a definition of a shift in active leadership in trauma resuscitation. This action occurs when a senior leader (an attending physician or a chief resident) takes over decision making and strategic direction of the team, assuming a more active and influential role in the team, or, conversely, when a senior leader recedes from strategic direction assuming a more passive and less influential role. In the examples below (Table 3-27), an EMS paramedic assumes the leadership role upon patient arrival to the trauma bay and orders an action, and a chief resident (more senior than the team leader) takes over the leadership from the team leader (examples italicized).

Table 3-27: Examples of Leadership Takeover.

ACTOR	ACTION	SUBJECT	COMMUNICATION
EMS paramedic	(talks to	TEAM)	*Let's re-confirm lungs sounds while we are here kids!*
Chief resident	(talks to	Team leader	*We'll do FAST after you finish, okay? Right?*
Team leader	(talks to	TEAM)	Yes.

Knowledge-based behaviors

Observations and interviews with trauma surgeons indicted that trauma team members rarely engage in knowledge-based behaviors. The team follows the ATLS treatment protocol with little time for free-form explorative knowledge-based behaviors. A few instances of knowledge-based behavior did emerge through observations and are manifested in the following actions, or subcategories: group decision making (i.e., several team members considering more options) and coaching (i.e., demonstrating or explaining a technical procedure to the members-in-training).

Group Decision Making: In this action, two or more team members collaboratively make a decision about the next step in patient evaluation. Communication exchange involves considering several options and then finally deciding on the most appropriate one. Group decision making typically occurs during abdominal ultrasound exams or when the team leader and other senior members examine chest and pelvic x-rays. Table 3-28 shows an example of group decision making (example italicized).

Table 3-28: Example of Group Decision Making.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Attending physician	(talks to	Team leader)	*You know what, you might first want to intubate him, you know what I mean...*
Team leader	(talks to	Attending physician)	*I think we should proceed with the chest tube first.*

Coaching/Educating: In this action, a team member demonstrates or explains a technical procedure to other members. This action typically occurs when a team member performs a procedure incorrectly, or when there was a training need to demonstrate or explain a procedure. Communication exchanges also include instructions on how to perform specific medical procedures. In the example below (Table 3-29), the attending physician is monitoring the junior resident's performance (example italicized).

Table 3-29: Example of Coaching.

ACTOR	ACTION	SUBJECT	COMMUNICATION
Attending physician	(talks to	Junior resident)	*Alright, (name), what have you got so far?*
Junior resident	(talks to	Attending physician)	(reports finding)
Attending physician	(talks to	Junior resident)	*Did you tell it anybody?*
Junior resident	(talks to	Attending physician)	No.
…		…	…
Attending physician	(talks to	Junior resident)	*Have you checked upper extremities?*

3.4.4. Reliability of the coding scheme

Upon establishing the main categories and subcategories in the behavioral coding scheme, coding instructions were written for coding the transcripts of videotaped trauma resuscitations (see Appendix C). Each speaker turn and action were coded as one or more of the subcategories shown in Table 3-1. All subcategories within higher-level coding categories are mutually exclusive. For example, a communicative action can only be coded using one verbal communication subcategory. Thus, "*110 over 83!*" is coded as a "Report." If a communicative action is a report of an evaluation finding, a code denoting information source can also be put in the appropriate column in the coding sheet. For example, "*110 over 83!*" is a report of the patient's blood pressure obtained by reading a value from the vital signs monitor. In addition to the code "Report," this communicative action is then coded as "Instrument Reading" to denote the source of information. Decision-making categories have meta-dimensional function and can, thus, be applied to communicative actions and nonverbal procedures. For example, the utterance "*Alright, let's take the patient to the OR*" is coded as a "Directive," but it also happens to be a "Takeover" because this utterance came from a chief resident who took over the leadership and made this decision. In short, while subcategories within the higher-level coding categories are mutually exclusive, the higher-level categories, themselves, are non-mutually exclusive. An example of a coded transcript is available in Appendix E.

Establishing reliability in qualitative research is important as it creates the foundation for credibility of the results obtained in the research. As Neuendorf (2001) notes:

> Given that a goal of content analysis is to identify and record relatively objective (or at least intersubjective) characteristics of messages, reliability is paramount.

> Without the establishment of reliability, content analysis measures are useless. […] without reliability, a measure cannot be considered valid. (p. 141)

One of the more popular methods for ensuring reliability of the measurement technique is to have two or more observers independently code the data or behavior (Runyon, Coleman & Pittenger, 2000). This method is called inter-coder reliability and examines how similar two or more coders can be with each other. A set of coding categories is then reliable if separate coding attempts result in the same content coding.

In this thesis, codes are not used to generate hypotheses about teamwork errors and no statistical tests are run with the coding. Main purpose of the coding scheme is to facilitate data analysis process. Rather than ensuring the highest level of coding rigor (needed for statistical analysis using the coding), the author of this thesis was mostly interested in doble-checking the robustness of the coding scheme. For these reasons, this thesis adopts a different method for establishing the reliability of the coding scheme, i.e., the intra-coder reliability. Intra-coder reliability examines how consistent a coder (the author) can become with himself or herself.

The sample used for testing the reliability of the coding scheme consisted of two transcripts (11.1% of the total of 18 transcripts). Transcript # 1 was first coded in June 2008 and contains 241 coding units. Transcript # 18 was transcribed and coded in December 2008, and contains 368 coding units. Recoding of the two transcripts was performed in May 2009, providing a long enough period between the two coding attempts for measuring intra-coder reliability (6 to 11 months, respectively).

The Cohen's Kappa coefficient (Kraemer, 1982) was used to determine the intra-coder reliability. The resulting kappa value was analyzed using the kappa interpretation scale suggested by Landis et al. (1977). According to this scale, kappa values higher than

0.81 show “Almost Perfect” agreement; values between 0.61 and 0.8 represent “Substantial” reliability; kappa values between 0.41 and 0.6 indicate “Moderate” agreement; values ranging from 0.21 to 0.4 represent “Fair” reliability; kappa values between 0.00 and 0.2 are regarded as showing only a “Slight” level of agreement; and finally, “Poor” agreement is shown by kappa values below 0.00.

To determine intra-coder reliability, the author of this thesis recoded each action unit in the sample transcripts and compared these results to the first set of codes. Separate reliability measures were obtained for each of the high-level categories, i.e., for the *Information acquisition and retrieval* categories, the *Communication and intervention* categories, and for the *Decision making categories* (Table 3-30). Statistical details on this procedure can be found in Appendix D.

Table 3-30: Reliability measures within a coder for each high level category (N = 609).

	Information acquisition & retrieval categories	**Communication & intervention categories**	**Decision making**
Percent Agreement	77.2%	93.3%	92.9%
Cohen’s *kappa*	0.697	**0.924**	0.582

The strongest agreement measure was found for the Communication and intervention categories, indicating an “Almost perfect” level of agreement (kappa value of 0.924). The subcategories with the most disagreements included Inquiries and Clarifications (e.g., inquiries were coded as clarifications six times). To resolve this ambiguity, coding instructions were modified to enable better discrimination between the two subcategories. Clarifications usually follow Reports and request retransmission of the same information, whereas inquiries can be initiated without a Report; or, if following a Report, only requests for additional information are made.

"Substantial" reliability was obtained for Information acquisition and retrieval categories (kappa value of .697). Most disagreements related to the sensing subcategory. The sensing subcategory turned out to be ambiguous because it requires distinguishing between four modes of information gathering, i.e., sensing via sight, touch, sound or a sense for elapsed time. If these modes are not included in the transcript, a coder can only try to determine the type of sensing modality from the context. A potential solution to this problem is to simply remove the sensing subcategory from the coding scheme.

The weakest agreement measure was found for the decision-making subcategories, indicating "Moderate" level of agreement (kappa value of 0.582). Because these subcategories represent a relational or meta-dimension for a given task, they are more difficult to distinguish from the transcriptions of video recordings. Disagreements within this high-level category can also be explained by the fact that these subcategories are not well defined, and better definitions need to be provided.

In addition to assessing intra-coder reliability, the behavioral coding scheme was verified with the attending physicians on the research team during group meetings. The surgeons approved the established higher-level categories, confirmed tasks and behaviors that are represented in the coding scheme, and assisted with providing examples and medical contexts for the subcategories. The surgeons also helped with ordering the categories and subcategories so that they logically followed the behaviors in the trauma bay. For example, the physicians typically start the evaluation process by observation and data gathering, thus, the observation category first.

3.4.5. Medical coding scheme

In addition to the domain-independent activities describing team tasks and communication, a domain-dependent, medical-task coding scheme was developed with

Table 3-31: An excerpt from the medical-task coding scheme.

MAIN CATEGORIES	SUBCATEGORIES		CODE
Primary survey	***A**: Airway*	Any assessment of airway patency	A1
		Chin lift/jaw thrust	A2
		Intubation	A3
		Cervical spine immobilization	A4
	***B**: Breathing and ventilation*	Chest auscultation	B1
		Chest inspection / palpation	B2
		Oxygen saturation	B3
		Respiratory rate	B4
		Administration of oxygen (mask, prongs, etc.) and ventilation	B5
		Chest tube placement	B6

the assistance of the trauma surgeons from RWJUH to account for the medical activities performed during a patient evaluation. Medical tasks were derived from the goals of the team activities driven by the ATLS evaluation protocol, and provided semantic context for the control tasks. An excerpt from the medical-task coding scheme is shown in Table 3-31. A complete medical-task coding scheme is included in Appendix C.

Existing research of highly dynamic teamwork typically uses a much coarser coding schemes (e.g., Xiao et al., 2003; Faraj and Xiao, 2006). In the current work, a combination of the behavioral, control-task coding scheme and the medical-task coding scheme described above enabled gaining important insights into trauma teamwork, such as who talks to whom (actors vs. subjects), who does what (actors vs. tasks), types of information exchanged, and the use of artifacts. Use of these detailed coding schemes also enabled quantifying teamwork and interactions in the trauma bay, which is one of the novelties of this research.

3.5. Transactive Memory Theory

One important aspect of trauma teamwork is that trauma teams rely heavily on collective memory and rarely use external memory aids. To help with interpreting results pertaining to cognitive aspects of trauma teamwork, this thesis adopts the use of *transactive memory theory* (Wegner, 1987).

The theory of transactive memory claims that "group behavior can be predicted through an understanding of the manner in which groups process and structure information" (Wegner, 1987, p. 185). Transactive memory refers to the specialized division of labor for handling information used by groups. As group members acquire specific roles and responsibilities, each individual learns and memorizes information from his or her specialty, as well as meta-information about who in the group knows what. To encode, store, and retrieve information from individual memory systems, group members perform "transactions" or communications, which makes this collective memory system "transactive." Such specialization and delegation reduces the cognitive load of each individual while enabling access to a larger pool of information across domains. As Hollingshead and Brandon (2003) write,

> A fundamental premise of transactive memory theory is that other people can also serve as external memory aids. Groups of interdependent individuals, by dividing up the responsibility for different knowledge areas and using one another as external storage devices, can create a memory system that holds much more information than any one of those individuals could retain alone. (p. 608)

The concept of transactive memory has been used widely in modeling the cognitive functioning of working teams (Moreland, 1996; Moreland & Argote, 2003; Akgün et al., 2006). As trauma team members observe and gather patient information, they memorize this information and transfer it verbally to the team leader who makes decisions. This means that team leaders and decision-makers rely on collective memory to acquire, store, and recall relevant information. Although members of trauma teams sometimes may not know each other by name, they are familiar with the responsibilities of all roles. Roles can be inferred from clothing and the tasks team members are performing. For these reasons, transactive memory theory is appropriate for studying the cognitive aspects of trauma teamwork, as well as trauma teams' communication practices. Transactive memory theory has already been applied towards the understanding of trauma teams' work (Xiao et al., 2002; Faraj & Xiao, 2006). However, the results of these studies are mostly qualitative and remain at a high level.

Communication plays a critical role in the conduct of trauma resuscitation. Due to the collaborative nature of assessment, it is critical that information about the patient and patient evaluation findings is transferred to all team members. Most of this information exchange is verbal, resulting in an internalized, collective memory. Only a few artifacts (e.g., the trauma flowsheet and the physicians' progress notes) help trauma teams externalize their cognitive processes, but these are rarely used for real-time data lookup.

In this research, the application of the transactive memory theory helped with the interpretation of the results from the analysis of communication patterns and enabled uncovering the ways in which group memory is used during trauma resuscitation, and where and when inefficiencies occur. It has been shown that group memory can lead to superior task performance (Moreland, 1996). By applying transactive memory theory to the results of this work, it was possible to answer whether or not reliance on collective memory improves trauma teams' work. Results of this analysis pointed to areas in which technologies can be integrated into the resuscitation process to support teamwork in trauma resuscitation.

3.6. Summary

The research in this thesis adopted both deductive and inductive approaches to studying the trauma resuscitation domain. The deductive approach was used for developing an overarching framework for the control-task coding scheme and for understanding the properties and limitations of the work domain. The inductive approach was used for developing the categories of the control-task coding scheme and for an analysis of trauma teamwork and team errors. In addition to these two approaches, a transactive memory theory was applied in order to interpret the cognitive aspects of trauma teamwork and communication patterns. The following chapter describes the methods that were selected for data collection and analysis.

Chapter 4

Methods

4.1. Chapter Overview

The purpose of this chapter is to describe the methods used for the dissertation research and the rationale behind selecting them. The problem domain required a broad systems approach that would enable systematic analysis of the trauma teams' work. Selection of the research framework entailed the use of observation, video recording, focus groups and interviews. The data was analyzed using summary statistics and a grounded theory approach.

4.2. Methodological Approach

To gain the requisite knowledge and understanding of how trauma teams work, this study employs a mixture of techniques for studying the domain. To begin with, the researcher became part of a research team comprised of three engineers, one computer scientist, three trauma surgeons, and one trauma nurse. This diverse group of experts resulted from the desire to holistically address the domain problems and the barriers to the effective introduction of technology in the trauma bay. The researcher has also been trained in the processes of trauma care in a one-day didactic course modified from the ATLS course to give her the needed skills to critically analyze the conduct of trauma resuscitations. Second, semi-structured interviews were conducted with trauma team members to assess the goals, tasks, information needs and information sources used during trauma resuscitation. Third, additional data was collected through focus groups with surgical residents and trauma nurses to assess each group's perception of their role and receptivity to new technology in the trauma bay. Finally, live trauma resuscitations were observed and videotaped to allow careful observation and coding of the activities of the resuscitation team.

The three research questions are addressed through a mixture of the complementary techniques described above:

1. The question of what constitutes trauma teamwork is addressed through the use of semi-structured interviews, focus groups, and observation.
2. The question about trauma team members' information needs and how information is exchanged within teams is addressed through an analysis of videotaped resuscitation events and observation.
3. The question of decision making in trauma resuscitation is addressed through observation and performing an analysis of the events taking place in a resuscitation using a simple model of trauma teamwork.

Identification of errors unique to teamwork and their causes is performed by applying a grounded theory approach to the data collected through video recording, observation, interviews and focus groups.

4.3. Research Setting

The Robert Wood Johnson University Hospital (RWJUH) is the main teaching hospital of the Robert Wood Johnson Medical School at the University of Medicine and Dentistry of New Jersey and is a Level 1 regional trauma center located in New Brunswick, NJ. A Level 1 center is the highest designation a trauma center can receive; it provides the highest level of specialty expertise and meets strict national standards as set by the American College of Surgeons (2008). Level I trauma centers such as RWJUH are preferred sites for the initial triage of seriously injured patients and are major referral centers for injured patients initially treated at other hospitals. The trauma center at RWJUH admits over 1200 trauma admissions per year, among which about 600 involve full trauma team mobilization. Patients treated at the trauma center have sustained major injuries in car accidents, intentional violence (e.g., gunshot or stabbing wounds), or falls. RWJUH is one of the three top-level centers in New Jersey and uses the same staffing and procedures as other high-level trauma centers in the US.

To record live trauma events, the trauma bay, a designated room in the emergency department for conducting trauma resuscitations, has been outfitted with two ceiling-mounted cameras and microphones. A wide-angle camera was mounted above the entrance to provide the view of the entire trauma bay. The second camera was mounted above the stretcher to capture the activities of workers gathered around the patient (see Figure 4-1). Privacy issues with human subjects have been carefully addressed through the Institutional Review Boards (IRB) of both the RWJUH and Rutgers University. A request to videotape live trauma resuscitations was approved by both institutions. The IRB approvals required informed consent for videotaping and have mandated that the videotapes be destroyed within 96 hours. The requirement for informed consent for the observational part of the research

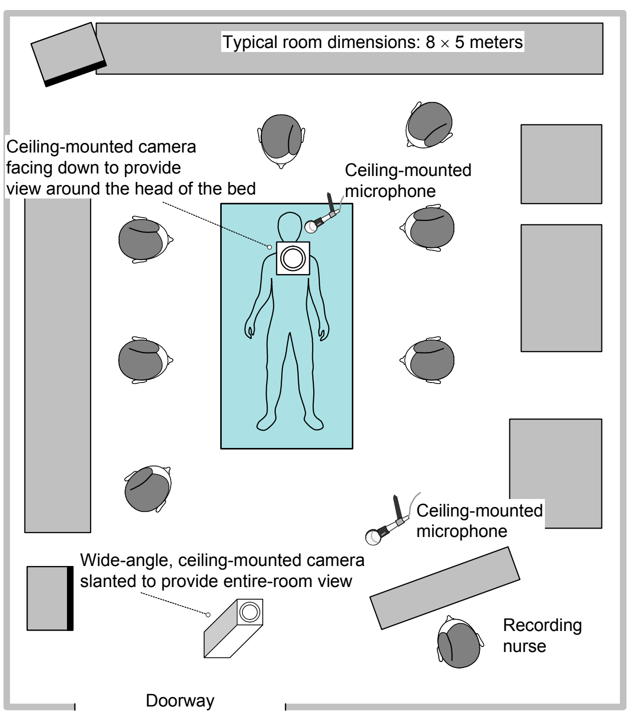


Figure 4-1: Trauma bay layout and positioning of the recording equipment.

was waived in accordance with the policy that such consent is not required when the research involves minimal or no risk to the subjects and does not adversely affect the rights and welfare of the subject.

4.4. Study Population

This research studied trauma teams that were involved in 60 trauma resuscitations, of which 18 were recorded. The selection of recorded resuscitations was not random but depended on the availability of the researcher or a health care provider to initiate the recording. The exact number of trauma team members involved in these resuscitations is difficult to determine because of the dynamic nature of a trauma team. Based on the signed consent forms for videotaping (a copy of the Informed Consent Form is included in Appendix A), it is estimated that observations involved about 250 health care providers including physicians, residents, nurses, technicians, anesthesiologists, pharmacists and medical students. Because the trauma team for any given resuscitation is drawn from a larger pool of health care professionals, written consents were obtained before the study began. One trauma surgeon declined to sign the consent form and, thus, be videotaped. This meant that resuscitation events in which this trauma surgeon served as the attending physician could only be observed.

4.5. Data Collection and Analysis

Data collection and analysis proceeded in two distinct phases, following the recommended strategies for *grounded theory development* (Glasser & Strauss, 1967; Strauss & Corbin, 1998). The grounded theory is used as the analytical method for the research reported in this dissertation because it allowed the researcher to capture the complexity of activities that were taking place in the trauma bay.

4.5.1. Phase 1: Data collection using interviews, observation, and recording

As the goal in this phase was to gain a fundamental understanding of the setting, the trauma teams, and their work practices, semi-structured interviews were conducted with one third-year resident physician, one emergency medical services (EMS) paramedic, and three attending physicians and trauma surgeons, one of whom was the chief of trauma and surgical critical care at the time the interviews took place. Separate focus groups were run with six fifth-year resident physicians and three trauma nurses, who, on average, reported 26 years of experience. Interview questions were focused on various aspects of trauma care. In particular, the participants were asked to describe the goals, tasks, information needs and resources, as well as the limitations they face in each resuscitation. The interview with a paramedic provided insights into the pre-hospital patient care and information handover. In two separate focus groups, trauma nurses and senior residents (who typically assume the team leader role) were asked to discuss their work practices. Additionally, their receptivity to new technology in the trauma bay was assessed. Interviews and focus group discussions were audio taped and transcribed. The interviewing and focus group protocols are included in Appendix B.

Over the two-and-a-half-year period (April 2006—December 2008), the treatment of 60 different patients was observed, of which 18 were videotaped. Additionally, three trauma simulations were observed and video recorded. Videotaping of simulations does not share the risks of videotaping actual resuscitations. Thus, no official permission was required to videotape and later use the recordings. The researcher logged a total of 60 days at the trauma center with many hours passing without trauma patients coming in. When possible, idle moments were used to conduct informal interviews with members of the trauma team and ask for clarifications of observations. Interviewing trauma team members immediately after the resuscitations was almost impossible since physicians and nurses followed the patient to the next hospital unit. Notes taken during the resuscitations were later augmented with details and summaries of impressions from the field. Copies of trauma flowsheets that represented patient status during the resuscitations were collected only for simulations. Still photographs of the trauma team, equipment and the room were also taken during simulations.

The four data collection techniques (observation, video recording, interviews, and focus groups) yielded a variety of data required to gain an understanding of the complexity of an information-intensive environment such as trauma resuscitation. This variety of data also allowed data triangulation, i.e., the use of multiple types of data and methods to ensure validity and reliability of findings. The following section provides details about the analysis of the video recordings.

Analysis of video records

Given the time limit of 96 hours for keeping the video records, it was necessary to develop a method that would a) preserve the richness of the video record once it is deleted, and b) allow for a detailed analysis of trauma teams' work and behavior. As described in Section 3.4, the behavioral control-task coding scheme was developed to identify trauma teams' activities so that accurate representations of teamwork could be produced. What was needed as well was an efficient transcription scheme that would facilitate data transition from a video- to a paper record. Although this section is called "analysis of video records," it might be more appropriate to think of this "analysis" as the "processing" of video records and transferring the content from one medium to another.

To analyze video recordings, a transcription scheme was developed based on the parallel columnar transcription scheme, which is commonly used in interaction analysis

(Jordan & Henderson, 1995). Interaction analysis is an interdisciplinary method used to investigate human activities such as talk, nonverbal interaction, and the use of artifacts and technologies in work settings. The basic data corpus used in interaction analysis is a video recording of an event, which allows multiple reviews of it and, thus, enables close interrogation of interactions going on in the event. Interaction analysis offers a number of transcription strategies to be used when analyzing video recordings. Transcripts containing parallel columns are useful for tracking multiple parallel activities in complex, information-intense work settings (ibid). The parallel columnar transcription scheme was found appropriate for the analyses of trauma teamwork since trauma resuscitation involves multiple activities (e.g., verbal communication, nonverbal behavior, and interaction with instruments) often happening at the same time. The extent and detail of the transcription scheme were determined by the analytic goals, as well as by the desire to capture the maximum amount of information given the limited time for video review. To gain insights into trauma teams tasks, information exchange, decision-making and communication practices, the focus was on analyzing team activities, such as who talks to whom (actors vs. subjects), who does what (actors vs. tasks), types of information exchanged and the use of artifacts. Nonverbal procedures were transcribed as well, but their detailed analysis was not possible due to the 96-hour limit for video review.

Transcribing the videos was a difficult and tedious process. Although resuscitation events lasted between 20 to 30 minutes, they were extremely fast-paced and information-laden. At times, there were several conversations happening simultaneously, with trauma team members performing many parallel tasks. On average, it took about 20 hours to transcribe one event that typically included >400 discrete tasks or communications showing the complexity of this work. To facilitate the transcribing process, open-source, free software called Transana (http://www.transana.org/) was used. Transana allows researchers to transcribe and analyze large collections of video and audio data. It was particularly suitable for transcribing video recordings of trauma resuscitations because it allowed parallel viewing and transcribing of the video. Completed transcripts were exported from Transana, transferred to a spreadsheet and segmented so that individual speaker turns and actions could be coded separately.

The author of this thesis did much of the transcription herself for several reasons. First, trauma resuscitation is a medical domain with many specialized words and jargon. Understanding what is said is a constructive process and ambiguous inputs are often unconsciously reconstructed based on the context (Hutchins, 1995). Without knowing the context, other transcribers would not be able to hear what the researcher—who was trained in the process of trauma resuscitation and had spent many hours observing the events—could hear in the video recordings. The language of trauma resuscitation is a foreign language to many people, and quality transcriptions cannot be expected from a transcriber who is not trained to understand it. Second, since there were many speakers at the same time, the fact that the researcher knew members of the team and could recognize their voices and faces in the video records, helped in distinguishing the identity of the speaker and his or her role. As mentioned already, roles of trauma team members can be inferred from the tasks they perform. Acquired knowledge of who in the trauma team does what helped distinguish the speakers in situations where it was not evident from the content of the statement who was speaking. Finally, in order to produce a good transcript one needs to view and listen to the recording many times. This repeated viewing not only

Table 4-1: Abridged excerpt from a transcript. Role acronyms are as follows: CCT (clinical care technician), ORT (orthopedic), REC (nurse recorder), TL (team leader), and PNR (primary nurse).

Line #	TIME (msec)	Medical Code	Behavioral / Communication Codes	ACTOR	ACTION	SUBJECT	COMMUNICATION
94	<225653>	C1	Report	CCT	(finishes measuring BP)		130 over 66
95		S8	Observation	ORT	(examines PTN's legs)		
96			Observation, Inquiry	REC	(talks to	TEAM)	Do you guys have anything other right now?
97			Observation	CCT	(approaches vital signs monitor, does something to it)		
98		C2	Inquiry	TL	(talks to	CCT)	Do you have pulse on him?
99		B3, C2	Response	CCT	(talks to	TL)	100%, heart rate 100
100			Acknowledge.	TL	(talks to	CCT)	Okay.
101		B1	Observation	PNR	(listens to breath sounds)		
102			Observation, Inquiry	REC	(talks to	CCT)	(Name), do you have any vitals for me?
103	<286135>	B3, C2	Report	CCT	(looks at the monitor, talks to	REC)	Yeah, 100% O2, HR 90

improved the quality of the transcripts but also helped the researcher learn what was actually going on in the event. Nevertheless, to ensure the accuracy of transcription, a trauma surgeon and a nurse on the research team verified complete transcripts while the video records were still available for viewing.

Given the 96-hour limit, the transcripts were coded after the videos had been erased. Upon completion of a transcription, each row was assigned one or more semantic codes in the appropriate columns in the coding worksheet. The codes belong to the behavioral control-task and medical-task coding schemes (described in Section 3.4). The author of this thesis coded the transcripts twice, with 6 to 11 months passing between the first and the second coding. Cohen’s Kappa was used to verify the reliability of the control-task coding scheme. Separate kappa values were calculated for the three higher-level categories. *Communication and intervention* and *Information acquisition and retrieval* categories obtained “Almost perfect” and “Substantial” levels of agreement respectively. These kappa values are considered to be an acceptable indicator of agreement above chance level. The *Decision-making* category attained “Moderate” level of agreement. (Detailed discussion of the reliability of the coding scheme is provided in Section 3.4.4.) An adapted excerpt of a coded transcript is shown in Table 4-1. In this example, line 99 shows a technician (CCT) responding (RS) to a previous inquiry (Q) by the team leader (TL). As their topic is about pulse rate, its matching medical code, which is C2 is placed in the medical code column of the coding sheet. The medical code for oxygen saturation (B3) was also added since the CCT included its value in his response. An example copy of a fully transcribed and coded resuscitation event is included at the end of the Appendix E.

By applying the behavioral- and medical coding schemes, it was possible to create accurate representations of the collaborative activities of trauma teams and a conduct detailed analysis after the video record was deleted.

It should be noted that trauma surgeons on the research team used the resuscitation transcripts to mark medical errors and inefficiencies. The surgeons used an error classification scheme adapted from Clarke et al. (2000) and marked the errors of commission, omission, and selection that they identified in transcribed events. This error analysis, however, only accounted for individual errors. Nevertheless, the errors marked by the physicians provided the basis for identifying team errors. In other words, they helped the author of this thesis to identify critical situations in the resuscitation events and to look for their potential causes in the work of the team.

4.5.2. Phase 2: Data analysis

The goal of this phase was to analyze the data collected through interviews, focus groups, observation and video recording.

Transcripts of recorded events were used to study the tasks and role assignments (e.g., what team members look at or do) and the context in which these tasks occurred.

Summary statistics were calculated for both control- and medical tasks. Data from interviews with trauma team members was used to support the analysis of tasks and role assignments. Transcribed interviews were analyzed using a data-driven approach. Statements describing task assignments and executions were extracted from each interview and grouped by themes.

To determine the information needs of trauma teams, all utterances that were coded as "inquiries" and "responses," in the transcripts were isolated. The grounded theory approach was applied to identify categories of questions from the data. For example, in the first resuscitation observed, it was found that the team leader inquired about the patient's name at the beginning of the event: "*Do you have name on him?*" Later, in the same resuscitation, the team leader repeated this question but posed it directly to the patient: "*What's your name sir?*" Based on these observations, it was postulated that trauma team members inquire about the patient's personal information when this information is not included in the initial EMS report. In the second resuscitation, no inquiries about the patient's personal information were posed. An analysis of the transcript revealed that the EMS paramedic reported the patient's name upon their arrival to the trauma bay. The third resuscitation observed confirmed the assumption made in the first resuscitation. The patient was brought in the trauma center and the EMS paramedics provided their initial report. Upon finishing the report, the team leader inquired: "*What's her name?*" Similarly, inquiries about the patient name emerged in resuscitation events # 4, 5, 6, 9, 10, 11, 12, 13, 14, 16, and 18. Based on these observations, the question category "patient personal information" was formed.

Additionally, by looking into the actors and subjects in the transcripts, it was possible to identify who in the team asked and answered questions. This analysis yielded the most common information seekers and information providers in the trauma bay. Trauma team members' statements describing information needs were also extracted from the interviews and focus groups, and added to the appropriate groups of questions identified through the analysis of inquiries. To represent common communication practices used for information exchange among the team members, summary statistics for directives, questions, replies, and other interactions were calculated.

A simple model of trauma teamwork was developed to analyze decision-making processes. Transcripts of recorded events were used to identify the most common decision making tasks by applying the codes from the decision-making category in the behavioral coding scheme. Data from observations was used to determine when in the process decision making occurs and what information is being used in the process.

Results obtained through the analyses of resuscitation goals and tasks, role assignments, information needs, and decision-making processes were then used as the basis for conducting the analysis of errors unique to teamwork and their causes. In other words, knowledge and understanding gained through answering the research questions helped with identifying team errors and their potential causes. It should also be noted that the medical errors committed by the trauma team members that were marked in the transcripts by the trauma surgeons served as the starting point for identifying critical situations that resulted in teamwork inefficiencies. The identification and analysis of team errors and their causes proceeded as follows.

Critical situations were first extracted from the transcript of resuscitation # 15, which was selected by the trauma surgeons as the most complex resuscitation observed. A grounded theory approach was then applied for establishing preliminary set of assumptions about team errors. This preliminary set of assumptions was verified against critical situations extracted from the transcript of resuscitation # 1. This step resulted in confirming some of the previously established assumptions or establishing new assumptions about team errors. Next, the critical situations from the transcript of resuscitation # 2 were extracted and verified against a refined set of assumptions about team errors. This process was then repeated for the remaining 14 resuscitation transcripts. With each new transcript, a set of assumptions about team errors was refined until a distinct set of assumptions (or themes) about teamwork errors emerged.

For example, in resuscitation # 15, the team leader found that the patient had unequal pupils, a signal of a potential injury. Instead of reacting to this finding immediately, the team leader proceeded with the evaluation ordering chest x-rays. Based on these observations, an assumption was made that a class of errors appears to occur when trauma teams fail to use weak diagnostic cues; rather, trauma teams wait until they obtain strong diagnostic cues, such as results from ultrasound exams or x-rays. The patient in resuscitation # 15 had sustained internal bleeding from a severe pelvic fracture, and this diagnosis was confirmed only after the team obtained results from x-rays. The assumption about this class of errors was confirmed in the second resuscitation, in which the patient's heart rate went up in the middle of the resuscitation. The team leader noticed this irregularity, but instead of treating it, he started the ultrasound exam to check for abdominal bleeding. The attending surgeon, who was standing next to the team leader, also did not react to the increased heart rate and suggested a pelvic exam as the next evaluation step. Similarly, in resuscitation # 17, the team had problems obtaining the patient's radial pulse. Rather than looking at this problem as a diagnostic cue, the team thought that the equipment was malfunctioning. They continued measuring the pulse using several different methods until they realized that the patient had lost a large volume of blood due to internal bleeding in his left chest and, thus, had no pulse to be measured. Although only several resuscitation events confirmed the assumption about this class of error, the trauma surgeons on the research team agreed that it represents an important error type that can have fatal consequences if not caught in time.

4.6. Summary

The purpose of this chapter was to describe the methods that were used in this research and why they were selected. Observation and video recording, followed by the interviews and focus groups were used as primary methods for data collection. Over the course of two and a half years, about 60 live resuscitations were observed, of which 18 were videotaped, transcribed, coded, and analyzed. Observation and video recording provided detailed information about the trauma teams' tasks, information needs, and decision-making process. Information obtained through interviews and focus group discussions was used to support and validate information gathered through observations and video recording. Identification and analysis of team errors and their causes was performed using the transcripts of videotaped resuscitations. A grounded theory approach was selected as the primary analytic approach and was applied to the gathered data for the purposes of error analysis. The following chapter describes the first set of results obtained in this research. It focuses on the description of the trauma resuscitation domain and provides answers to the first research question of what constitutes the trauma teamwork.

Chapter 5

Work Domain Description and Trauma Teamwork

5.1. Chapter Overview

This chapter describes the structure of the work domain. The purpose is to help the reader understand the complexity of the trauma resuscitation domain, its goals, and associated tasks. The chapter also introduces trauma resuscitation terminology, trauma team members, current work practices, and instruments and tools that are being used for patient evaluation. The description of the work domain roughly follows the cognitive work analysis approach. The chapter starts with an overview of trauma resuscitation. This is followed by descriptions of the work domain, trauma resuscitation goals and tasks, trauma team composition, and trauma bay equipment. Data presented in this chapter was collected through interviews and focus groups with trauma surgeons, residents, nurses and an EMS paramedic, and through observation. Additionally, some practices for trauma resuscitation were also found in the current medical literature (American College of Surgeons, 2008).

5.2. Trauma Resuscitation Overview

The purpose of trauma resuscitation is to identify and immediately treat life-threatening injuries. The team must stabilize the patient, determine the extent of the injury and develop a treatment plan to be carried out during hospitalization. While resuscitations differ based on the type of injury, several common features are observed (Figure 5-1). Before the injured patient arrives in the emergency department (ED or ER), members of the trauma team are notified by beeper or by phone. Teams can vary based on anticipated need and include the attending surgeon, residents, an anesthesiologist, an

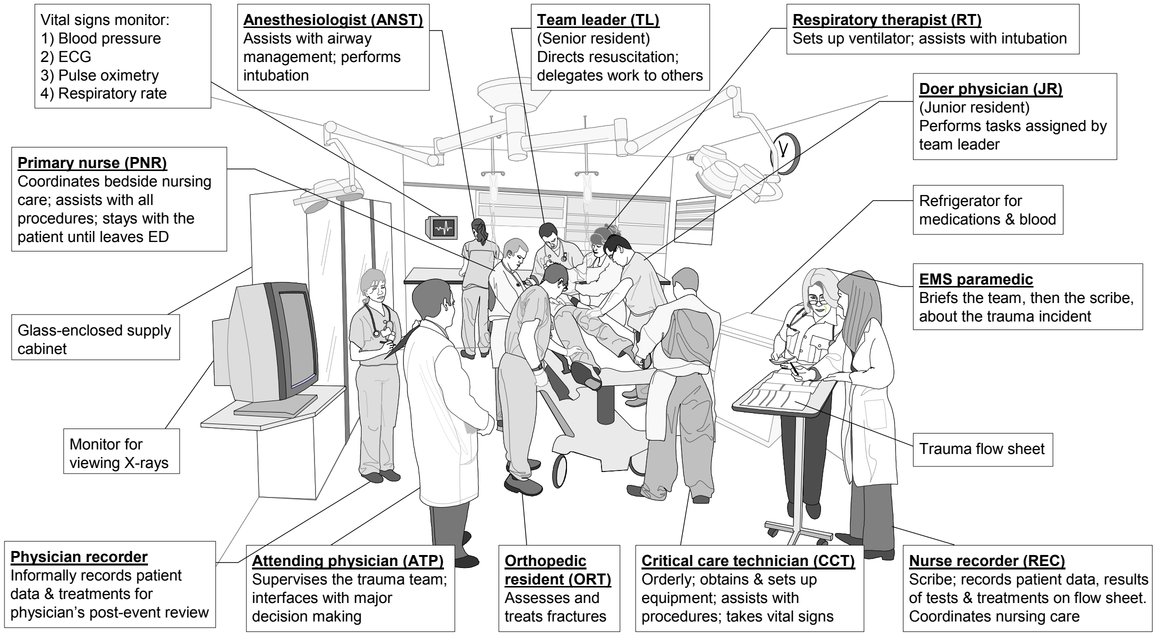


Figure 5-1: Emergency department (ED) trauma bay (ER): typical actors and artifacts in a trauma resuscitation event.

orthopedic surgeon, nurses, a respiratory therapist, a pharmacist and an x-ray technician. They are usually called from their regular duties because most are not dedicated only to trauma care. Other members of the team, including the attending physician, may not be in the trauma bay during initial evaluation. While a core team is present through the entire effort, some workers may leave and return and others may join the team after the evaluation has started with additional specialists called as needed. The team may have as few as seven members or more than 14 depending on ED staffing, time of day and anticipated severity of the injury.

The roles and responsibilities among team members are precisely defined to avoid redundancies and ensure completion of required tasks (Figure 5-1). The *team leader* (usually a senior resident) supervises patient care, makes major decisions and delegates work to team members. The individual designated as the team leader can change between residents and attending physicians depending on the condition of the patient, and the skills and availability of the individuals (Xiao et al., 2003; Klein et al., 2006). The team leader is assisted by another resident (usually a junior) who performs hands-on evaluation and treatment. An anesthesiologist assists with the management of the airway and an orthopedic surgeon manages orthopedic injuries. One nurse is dedicated primarily to the care of the patient (the primary nurse) and is aided by another nurse (the nurse recorder or scribe). Other team members are shown in Figure 5-1.

The conduct of the evaluation proceeds in a standard fashion using the ATLS protocol, which provides a common language and framework for trauma resuscitation around the world. The first phase of ATLS is a rapid evaluation for identifying life-threatening injuries (*primary survey*). The steps include evaluation and treatment of airway injuries (Airway [**A**]), which is then followed by an evaluation of the patient's respiratory system (Breathing [**B**]), an evaluation of the patient's blood-circulation status (Circulation [**C**]), and by a neurological assessment (Disability [**D**]). This initial evaluation is followed by the *secondary survey*, a detailed assessment to identify other injuries. These steps are then repeated as needed to determine changes in patient status and to monitor the impact of received treatments. The individual designated as the team leader may change between residents and attending physicians depending on the changing condition of the patient, and the skills and availability of the individuals involved (Klein et al., 2006). Other team members may also change their roles depending on need.

In current practice information is transmitted mostly verbally. Although some documentation is created during the resuscitation event, i.e., a trauma assessment flowsheet and a physician's record, they are rarely used in real time, and their purpose is mainly archival. Some attending physicians maintain handwritten notes, while in other cases a medical student maintains the notes for the attending physician. The records include results of the physical examination, vital signs, blood analyses, and x-ray tests.

In general, trauma evaluation uses a "by default" system, i.e., everything is assumed normal unless evidence of an injury or abnormality is found. While vital signs such as pulse, blood pressure, respiratory rate and oxygen saturation may be obtained digitally, monitoring requires that team members look at display monitors on a periodic basis. Audible alerts are available for extreme values, but the displays are visually checked for minor but important variations. Because most emergency departments do not have electronic monitors integrated with the medical record, this display data is usually recorded by hand.

In most cases, the patient evaluation in the trauma bay lasts between 20 to 30 minutes. The patient is mobile, may temporarily leave the emergency department for additional tests such as a CT scan, and may return for further evaluation or treatment. Paper records are transported with the patient and are not available for contemporaneous review by team members who are not present at the patient bedside.

5.2.1. Before patient arrival

Before patient arrival, the emergency medical services (EMS) crew transporting the patient notifies the trauma center via radio or cellular link. An ambulance has a radius of coverage of about 20-25 miles from the trauma center. The ambulance driver (EMS paramedic) calls the hospital and provides pre-arrival information about the patient. The pre-arrival information typically includes the estimated time-of-arrival (ETA), number of incoming patients, mechanism of injury and key information about the patient status (e.g., vitals signs and findings from physical examination). This pre-arrival information is primarily used for team preparation and has little impact on patient care due to the limitations of the pre-hospital information transfer system.

The EMS dispatcher receiving the call breaks the received information into two levels. The first-level information is sent to the telephone operator, who distributes information via trauma pagers. The notification sent via pagers typically contains the following information:

trauma alert code, transportation-means, mechanism of injury, age, ETA

Example: "Trauma alert, ground, fall, adult, 15 min"

Upon receiving pre-arrival notification, trauma team members immediately assemble in the trauma bay. The notification via trauma pagers is sent only once. The operator may send an update if he or she receives it from the EMS dispatcher, e.g., updated ETA. Reminders are never sent over the pager. Instead, the pager continues to beep periodically for several minutes if not checked, and then stops.

The second-level information is sent to the emergency department head nurse, who relays this information to the trauma team members as they assemble in front of the trauma bay, waiting for the patient. During this process, information is often lost or distorted, which is why trauma teams mainly rely on verbal reports obtained directly from the EMS crew after arrival to the trauma bay. The notification sent to the head nurse typically contains the following information:

(a) Unit and level of provider (who and what)
(b) Estimated time of arrival
(c) Patient's age and sex
(d) Chief complaint
(e) Brief, pertinent history of the present illness
(f) Major past illnesses
(g) Mental status
(h) Baseline vital signs
(i) Pertinent findings of the physical exam
(j) Emergency medical care given
(k) Response to emergency medical care

If time allows, the head nurse may also summarize this information on the whiteboard outside the trauma bay. The purpose of the whiteboard information is to avoid duplicate briefings, since care providers may show up at different times. Once recorded, information on the whiteboard is rarely updated. Rather, updated information is relayed directly to the trauma team members and the recorder who documents the trauma event.

Occasionally, the EMS paramedic transporting the patient fails to call in advance, which results in a patient arriving without warning. In this case, the trauma team is issued a message over the pager saying: "*Trauma alert in the ER now*." As reported by the nurses during a focus group discussion, the immediate trauma alert is less preferred since it leaves no time for preparation.

Trauma alert imposes some restrictions on the use of resources in the hospital. Trauma patients have priority over other patients. This means that the operating room and the CAT scan facility are put on standby in case they are needed for the trauma patient.

5.2.2. Upon patient arrival

Trauma patients can arrive either by ground or by air. When the patient arrives by air (helicopter), several trauma team members first assemble at the helipad where they receive the patient and the initial EMS report. Upon arrival to the trauma bay, a team member who was present at the helipad repeats the report for the rest of the trauma team. When the patient arrives by ground (ambulance), information handover occurs in the trauma bay only. Located near the ambulance entrance is an enclosed decontamination area with a full shower to treat the patients that have been exposed to potentially harmful agents.

Upon arrival, the patient is assigned a number and tagged by a bracelet with a patient ID on it. The patient's medical record is usually not available, particularly not for children.

During the patient handover, the EMS crew briefs the trauma team providing an initial report verbally, which lasts up to five minutes. In this report, the EMS crew introduces the patient by name (if known), summarizes the pre-arrival information, and provides additional information that was collected but not transmitted. Upon finishing this initial report, a member of the EMS crew provides more details to the nurse recorder who documents this pre-arrival information on a trauma flowsheet. Unless called to another duty, the EMS crew stays in the trauma bay briefly to answer questions.

5.2.3. Transfer to the trauma bay stretcher

There is a ceremonial pause, either at the trauma bay doorway or just as the patient is about to be transferred on the trauma stretcher (usually the latter case). This symbolizes the handover of responsibilities—from the EMS crew to the trauma team.

The two beds are aligned in parallel for the transfer. While being transported from the EMS vehicle to the trauma bay, the patient is connected to a portable vitals signs monitor. To maintain constant patient monitoring, the EMS crew and the trauma team must synchronize their connecting the patient to the trauma bay vital signs monitor and disconnecting the patient from the portable, EMS monitor. The team leader's goal in this transition phase is to establish initial patient status, which includes vitals signs information such as heart rate (pulse), respiratory rate, and oxygen saturation (S_pO_2). If available, latest vital signs are obtained from EMS paramedics, because it takes time to connect the patient to the trauma-bay vital sign instruments and obtain the initial values.

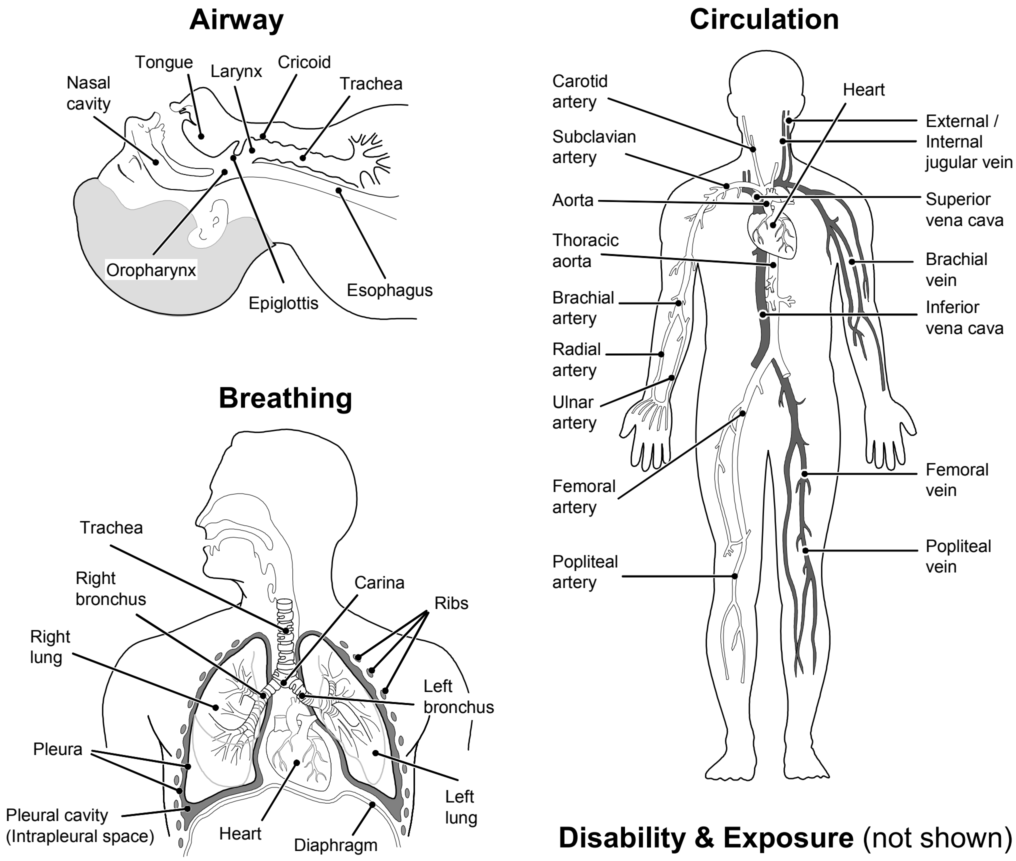


Figure 5-2: Physiological systems considered by the trauma team.

5.3. Work Domain Structure

Trauma is a blunt or penetrating external force exerted on the body resulting in an injury. Resuscitation goals and tasks are determined by the anatomy and physiology of human body, as shown in Figure 5-2. The most acutely important function is maintaining cell perfusion with oxygen, since most organs will die within a few minutes if lacking oxygen. Oxygen enters the body via the airway, is bound to blood cells in the lungs, and is carried around the body via the circulatory system. A small fraction of the instruments currently available for measurement and intervention are shown in Figure 5-3. A detailed description of trauma bay equipment is provided in Section 5.6. The purpose of this figure is to impress upon the reader that this is a very complex environment with multiple

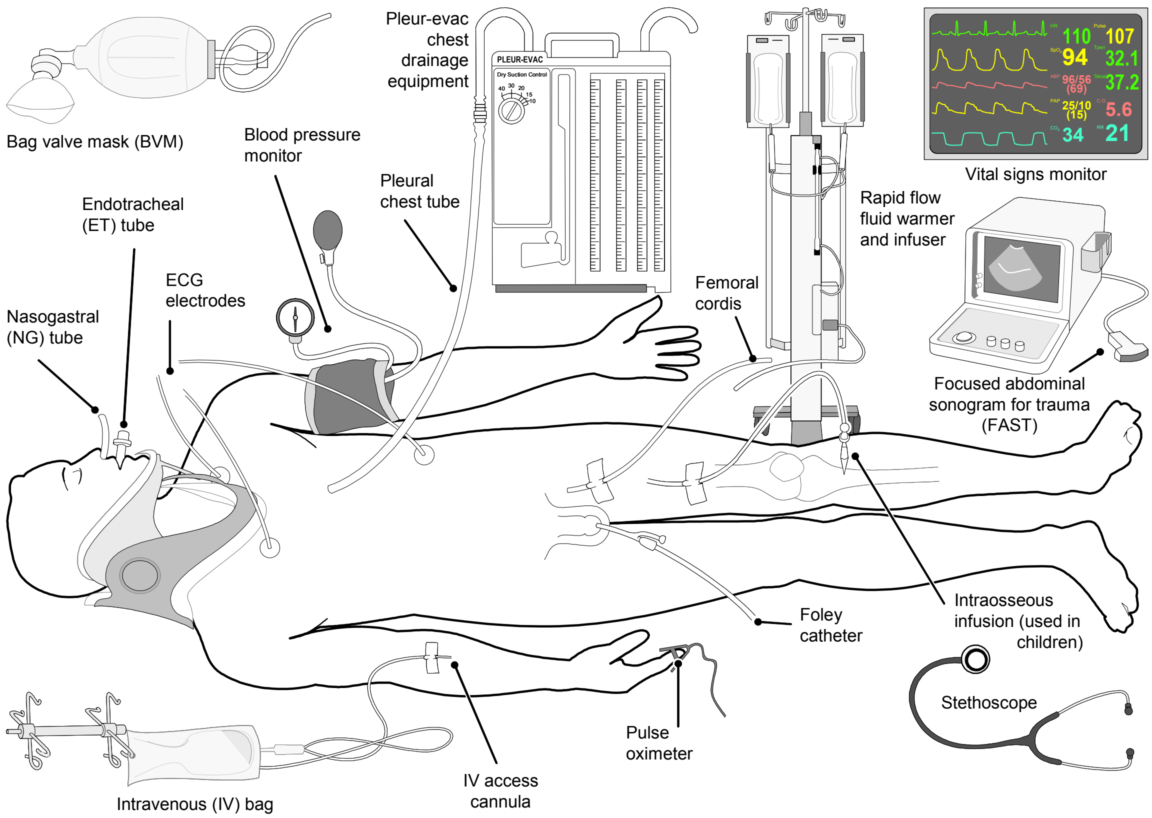


Figure 5-3: Typical instruments for measurement and intervention during trauma resuscitation.

tasks and distracters competing for the teams' attention. Each measurement method has limitations on accuracy and reliability, and each intervention method carries risks associated with it. Not every team member is qualified to do everything. Some tasks are carried out only by trained staff due to the associated risks.

Many physiological variables can be measured by multiple instruments. For example, pulse (or heart rate) can be measured via ECG electrodes or the pulse oximeter. Blood pressure (BP) is measured both automatically and manually. Automatic recording of the BP samples is continuously displayed on the vital signs monitor. The automatic monitor is set up to check the patient's BP every 1–5 min. Because the automatic measurement is not as reliable as the manual one, a technician usually obtains manual BP at the start of the evaluation to ensure that the automatic measurement is valid.

Some physiological variables are correlated. For example, the heart rate gets higher when oxygen saturation (S_pO_2) gets lower. The pain scale is considered one of the vital signs. High pain brings on high blood pressure and/or heart rate. However, to estimate the pain scale, the care providers have to rely on their intuition.

Vital sign monitors provide a range of programmable alarms to alert the care providers of abnormal values of the patient's physiological variables. However, it appears that these are set to a default value and rarely modified to tailor to the patient's age or chronic condition. There are also audio signals associated with different variables; a periodic audio tone is sounded such that

- Tone pitch encodes the blood oxygen saturation (S_pO_2)
- Tone frequency encodes the pulse (heart rate)

Although considered as a complex, socio-technical system, trauma resuscitation lacks effective information technologies for supporting teamwork or communication. Instruments and technologies shown in Figure 5-3 are rarely linked. Each instrument helps with monitoring a single patient parameter, but they do not integrate into a single system for synthesizing acquired information into a meaningful output.

5.4. Trauma Resuscitation Goals

Section 3.4. provided high-level descriptions of trauma resuscitation goals, tasks and procedures for the purposes of developing a behavioral, control-task coding scheme. The purpose of this section is to further describe the goals of trauma resuscitation and how are they achieved.

A *goal* is something a person wants to achieve. When translated into the trauma resuscitation domain, a goal would be maintaining the patient's airway unobstructed. A *task* is a means of achieving a goal. For example, to free the airway, the care provider may perform endotracheal intubation. As explained in Section 3.4, there are three types of tasks commonly found in trauma resuscitation: observation, decision-making and intervention. A *procedure* is a sequence of actions carried out to accomplish a task. For example, the task of establishing an intravenous (IV) access is accomplished by carrying out the following procedure: (i) apply antiseptic to the skin area; (ii) insert the needle; (iii) slide the plastic cannula over the metal needle; (iv) remove the needle; (v) secure the cannula in place using tape.

Goal achievement is defined by the values of observable parameters, known as system state variables. In the case of trauma resuscitation, system state variables are observable physiological and anatomical parameters, such as blood pressure and oxygen saturation. By observing the actual values of these variables and comparing them to the goal values, the team knows whether or not they are reaching the goal.

Some of the key resuscitation goals are shown in Figure 5-4. The goals are associated with physiological systems and organs of the patient's body. Because these goals are intrinsic to human body, they remain invariant for the duration of resuscitation and their achievement signals the completion of resuscitation. To establish the achievement of these goals, the trauma team members must observe and evaluate the patient's clinical signs (state variables), some of which are also shown in Figure 5-4. These goals are aimed first at eliminating or resolving the conditions that are an immediate threat to life. This is the primary survey part of the ATLS protocol. The actual values of the state variables associated with these goals must be frequently reevaluated as part of the ongoing evaluation until all the goals are deemed accomplished, and the

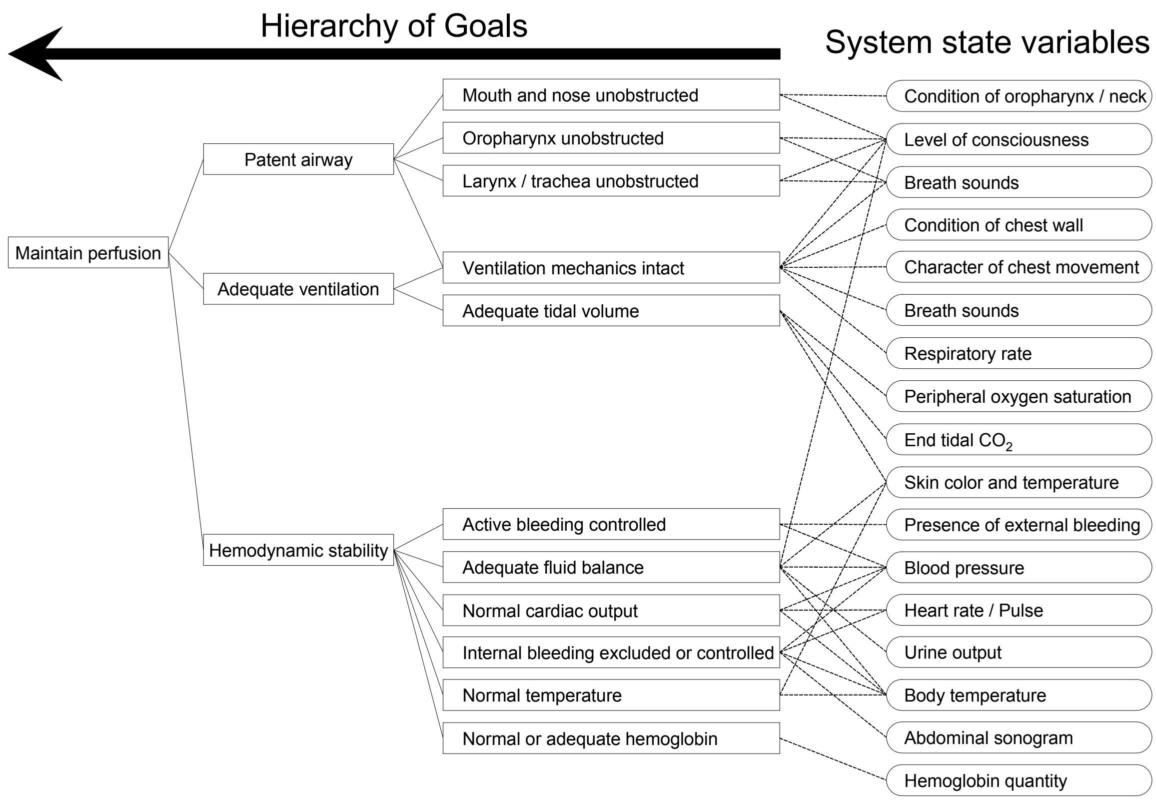


Figure 5-4: Some resuscitation goals and the associated (observable) state variables.

patient is transferred to inpatient care. Evaluative tasks that identify and treat injuries that are a potential threat to life belong to the secondary survey part of the ATLS. It must be emphasized that, should a patient's condition deteriorate during the secondary survey, it is essential to return to the primary survey and resuscitation, in case a new life-threatening condition has developed or an already existing one has been missed.

As Figure 5-4 shows, there are many goals to be achieved, making trauma resuscitation a very complex problem. The complexity is increased by the degrees of dependence among the goals. There may also be risks associated with achieving particular goals. Some medical conditions are very complex, with no generally accepted resuscitation procedures. These situations require an experienced team leader who is aware of the potential pros and cons of either approach to make an appropriate decision.

As the evaluation progresses (i.e., the observation tasks are successfully completed), the trauma team keeps track of yet-to-be-achieved goals. To realize the unachieved goals, the team members need to perform certain tasks. Each task can take a different amount of time to complete and even for the same task the performance time varies depending on other parameters. Some tasks, such as reading a parameter value from a vital signs monitor, are quick, while others, such as endotracheal intubation or ventilation, can take a relatively long time. Some tasks require simultaneous cooperation by multiple actors. For example, to examine the patient's back, the patient should only be moved by a well-coordinated "log rolling" technique involving four team members, particularly if a spinal injury is suspected.

5.5. Resuscitation Team Composition

The resuscitation team composition is decided as follows.

5.5.1. Resuscitation team summoning

At any time, there is a set of health care providers in the hospital carrying a special trauma pager, which is like a *token*. Team summoning is done by polling indiscriminately all the people carrying the token, rather than by calling for each person individually, by name. The telephone operator issues a "Trauma alert" message to the list of people carrying the pagers. The list of providers on call is automated, rather than paper-based. To ensure the system backup, more people are paged than needed. Additionally, there is a morning check that all pagers are working.

The initial team composition is always the same, i.e., everybody who is paged comes down to the emergency department and waits for the patient to arrive to the trauma bay. Based on the initial patient evaluation, the decision is made as to who gets to leave or stay. For example, an anesthesiologist responds to every trauma alert, even if the pre-arrival notification states that the patient has clear airway. The anesthesiologist has to wait until the team leader examines the patient's airway. If the patient's airway is stable, the anesthesiologist may leave. When leaving the trauma bay, team members usually announce their departure so that others in the team are aware of their absence, in case the patient's condition deteriorates and their help is needed. Consider the following excerpt from the field notes taken during resuscitation # 12:

> A young adult male, struck by a car, is brought to the trauma center. The patient lost consciousness en route and an EMS paramedic performed intubation to secure the patient's airway. As the EMS crew brings in the patient, the respiratory therapist pumps oxygen into the patient mouth using a big blue reservoir bag. While the patient is being transferred from one stretcher to another, the anesthesiologist enters the trauma bay, stops by the recorder's table, and tells his name. The recorder writes his name in the trauma flowsheet. The team leader starts evaluating the patient, first listening to his breath sounds and then checking for pulses. The anesthesiologist walks to the patient side and talks briefly to the respiratory therapist who is still pumping the oxygen. After listening to the team leader's reports for a few minutes, the anesthesiologist heads to the exit. Just before leaving, the anesthesiologist turns to the team and says: "*Anesthesia is leaving, give me a call if you need me.*" The team leader raises his head and nods to the anesthesiologist.

5.5.2. Pager assignment procedure

On a given day, the care providers on call are assigned the pagers. The trauma chief usually carries one pager at all times. The attending physician, who is on call for the day, also carries a pager. Some care providers may carry a pager at all times and ignore it if they are not on call. Pagers may also be passed from one person to another.

Residents

A residents' responsibility is to pass their assigned pager only to a provider with equivalent skills. For example, a chief resident (senior resident) will not pass his or her beeper to an intern. In this way, a problem of getting an unqualified person to show up in the trauma bay is avoided. The "token" system of summoning the core members of the team based on the possession of a trauma pager appears to be efficient. However, the pager does not allow two-way communication, which is often necessary to summon additional specialists or care providers. The following statement given by a senior resident (R2) during a focus group discussion illustrates this problem:

> “ […] we spend a lot of time paging people and calling people, like, we need nurse or surgeons to be notified, we need this person, and that person, and then when you page someone to a telephone that’s on a wall, you are anchored to that telephone. If we leave and go somewhere else, and the person calls back, we are no longer in communication. Our pager system cannot really receive, you cannot page someone to your pager, and a lot [of] us started using cell phones in the hospital, but in some areas [of the hospital] you cannot receive cell phones…”

Nurses

A charge (or head) nurse for the day carries a trauma pager, and if he or she cannot attend to a trauma patient when summoned, they would designate another nurse as a substitute. Reassignment usually goes without problems because the nurses are adjacent to the trauma bay and can quickly adjust to the needs of the trauma team.

The hierarchy among nurses is not as well developed as it is with physicians. There is a level playing field in nursing. A charge nurse is nominated on a daily basis. This nurse has a leadership position, but this is not a permanent appointment; they may be re-appointed at any time, especially if they prove good at their job. The responsibilities of the head nurse include making task assignments and “troubleshooting,” which is an administrative role rather than direct patient caring. The charge nurse decides who will play the role of the primary nurse (bedside nurse) and who will be the nurse recorder (scribe). This assignment process was also confirmed by one of the nurses (nurseTG) during a focus group discussion:

> “ […] Charge nurse is the one who has the knowledge of what’s going on in the whole department, the acuity, the volume, [what’s going on] with the staff nurse

> who maybe the trauma nurse. The charge nurse is the first one who's going to take the responsibility. For example, this weekend we had three trauma alerts within 40 minutes, and one of them was multiple, and the charge nurse had everything organized: I was primary on the first trauma, and that's a given because I was trauma nurse that day; for the other two patients coming in, she stood there and gave the orders: 'You're primary nurse, this will be your back-up, you're primary nurse, this will be your back-up,' and then when the fourth one came in, she could pull from the other parts of the ER, for instance, from non-urgent, and perhaps even from the urgent, and she kept everything going, everybody had a nurse, a primary, and everybody had a scribe."

5.5.3. Team composition

As described above, the initial team composition is always the same, i.e., everybody who is paged assembles in the trauma bay. The decision is then made as to who gets to stay or leave immediately. This is an important decision, decided or approved by the team leader, unless the attending physician is present. During the resuscitation, as the patient's condition improves, the team members are slowly dispersing and only the primary nurse, the nurse recorder, the technician, the team leader and the attending physician stay until the patient leaves the trauma bay.

When trauma team members walk into the trauma bay, they know their roles. However, they do not necessarily know the roles of others. This is usually resolved by cue recognition (e.g., roles can be inferred from the color of the robe or from the task one is performing), or by explicit querying: "*What is your role?*" For example, in the first simulation, the nurse recorder asked if the attending physician was present and then inquired about this name: "*Trauma attending? What's the last name?*" Similarly, in resuscitation # 12, the recorder needed the names of all physicians present in the trauma bay. He turned to the junior resident and asked the following:

Recorder1	(talks to Junior)	*You know who's the team leader?*
Recorder2	(talks to Junior)	*Who's the attending though?*
Junior	(talks to Recorder1)	[*Spells out the team leader's name*]
Recorder1	(writes the team leader's name in the trauma flowsheet)	

Recorder1	(talks to Junior)	*And you are?*
Junior	(talks to Recorder1)	[*Tells his name*] *And the attending is* [*name*]
Recorder1	(writes both names in the trauma flowsheet)	

It is important that team members know who in the team has what role so that tasks and responsibilities can be properly assigned.

The attending physician often comes in late as he or she can be held up by an ongoing surgery in the operating room. Sometimes, the attending may not show up at all unless explicitly called. In an interview, a trauma surgeon (attending#1) described the overall role of the attending physician as follows:

> "When I walk in [the trauma bay], I watch what the team leader is doing. I may look at the vital signs monitor and stand back and watch what the team leader is doing and listen to information that he provides. Usually I don't comment if everything is proceeding normally, I just allow process to occur. The only time I intervene is if there is some task that other people wouldn't able to do. I am just another set of hands, getting an overview of what's going on. I give feedback to the team leader if there is some deviation from the plan."

The level of involvement may differ from one attending physician to another. Over the course of the study, a total of seven attending physicians were observed. While each had a different style of working, they all acted in a similar way: they would come down to the trauma bay, inquire about the patient status directly from the team leader or the nurse recorder, observe the evaluation process and intervene if necessary. Generally, the attending physician is interested in a "big picture," and rarely interacts with the patient. As another attending physician (attending#2) put it succinctly:

> "We typically ask what's in it for me, what's important for me, what I need to do, is the situation under control, when can I go home… Attending needs a big picture!"

The primary role of the nurse recorder (also called the scribe or backup nurse) resembles that of a court stenographer, producing a record for assessment of on-going care and post event review. The nurse recorder rarely interacts with the patient during resuscitation. For these reasons, there are no free-form observational notes on the trauma flowsheet. The multiple page trauma flowsheet has designated areas for specific information such as demographics, mechanism of injury, physician response times, vital signs, location of injuries, diagnostic and therapeutic procedures, medications given, and final disposition.

Observational data indicated that the nurse recorder had additional roles that went beyond archival duties. First, it was observed that the nurse recorder played a key role in reminding team members about skipped tasks. For example, if the vital signs were not reported for an extended period, the recorder prompted the team to check on them. The recorder also reminded the team about evaluation steps that were skipped. In the example below, the team leader assessed the patient's airway (step A), breathing (step B) and circulation (step C) and moved on to examination of the patient's back injuries (log roll, step E). By seeing the missing fields in the flowsheet, the recorder realized that the team leader skipped the neurological exam (step D) and asked for any findings about pupils:

> The team leader and chief resident discuss findings from the patient's log roll and medications given so far. The chief resident orders a dose of morphine and the pharmacist starts preparing it. At this point, the nurse recorder glances at the trauma flowsheet and turns to the team leader: "*How about the pupils or anything? Belly? Belly soft?*" The team leader first confirms that the patient's abdomen is soft and then reaches for the penlight to assess the patient's pupils.

Second, the recorder "regulated" the environment. For example, the recorder asked people to leave the room if it was too crowded as there were often onlookers without a specific role. Or, when the room was noisy and people were not able to hear each other, the recorder requested silence. The following excerpt from the field notes taken during resuscitation # 18 illustrates this secondary role of the nurse recorder:

> The attending physician arrives at about 11 minutes after the patient was brought in the trauma bay. The patient has sustained four stab wounds and the team leader

> is considering inserting a chest tube. The attending physician starts discussing the patient's condition with the team leader. There are 13 people currently in the room, five of which are involved in direct patient care. Those that are not involved in the patient care are dispersed around the room, observing what is going on. The nurse recorder has problems hearing the technician who is reporting vital signs. She asks for vital signs to be repeated. Soon after, the recorder reports the results from a blood test, but the team leader cannot hear her. The recorder then speaks out loud: "*If you guys don't need to be in here, please step outside!*" After hearing the recorder, six people start leaving the room. The recorder acknowledges this by saying: "*Thank you!*"

The recorder also acted as a point of contact between the trauma team and other hospital units. The recorder paged other providers who were needed in the trauma bay and arranged for follow-up testing, such as CT scans. The recorder also acted as an interface between the trauma team and the unit clerk, channeling patient information needed for administrative paperwork.

Finally, observational data revealed that the "recorder's corner" (Figure 5-5) played an important function in supporting the conduct of trauma resuscitation by serving as an information hub. The recorder's corner is equipped with basic office supplies and a telephone for calling other hospital units. The printer is available for making stickers for labeling patient records and blood specimens. The recorder's table is portable and has documentation forms prepared on it. Trays on the wall contain additional flowsheets and other supporting documents. Trauma team members came to the recorder's table to sign in upon their arrival, take patient stickers, fill in forms, ask questions, or

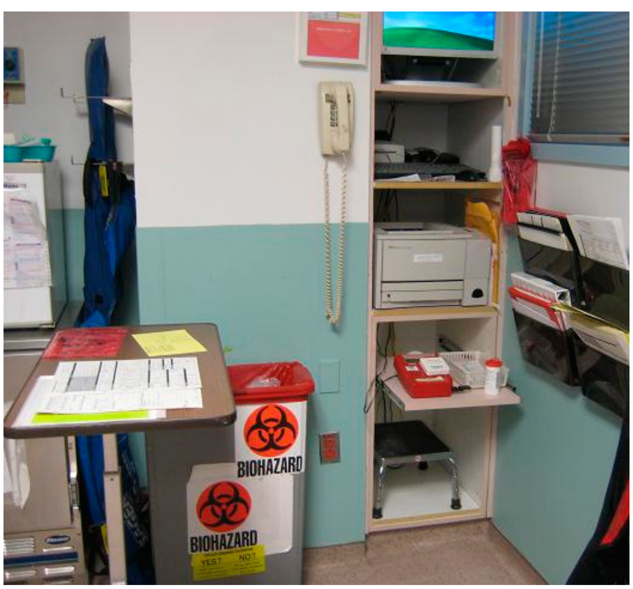


Figure 5-5: Recorder's corner.

Figure 5-6: Arrangement of equipment, tools and instruments in the RWJUH trauma bay.

clarify patient information. After finishing the initial report for the trauma team, paramedics often approached the recorder's table and provided additional details to the recorder. Towards the end of the resuscitations, the physicians came to the recorder's table to copy patient information from the flowsheet to their notes.

5.6. Trauma Bay Equipment

Typical equipment found in the trauma resuscitation bay of a Level 1 trauma center in the U.S. includes a variety of items, some of which are illustrated in Figure 5-1 and Figure 5-3. Arrangement of equipment, tools and instruments in the RWJUH trauma bay can be seen in Figure 5-6. The room dimensions are 23′×14′4″. Larger equipment is located outside the resuscitation bay and is brought in on a per-need basis.

Figure 5-7: Airway-related equipment. (a) Intubation equipment. (b) Airway tubes. (c) Face masks and Cervical collars. (d) Oxygen outlets.

Airway equipment

Most airway-related equipment is located on or above the workbench in the back of the room, at the head of the stretcher (Figure 5-6). Basic airway equipment includes: a laryngoscope, an instrument used to examine the larynx and to facilitate intubation of the trachea (Figure 5-7(a)); endotracheal- and nasogastric (NG) tubes (Figure 5-7(b)); cervical collars and face masks (Figure 5-7(c)); valve masks (also known as ambu bags); and, a ventilator.

The ventilator is located in the hallway adjacent to the trauma bay. It can be wheeled in when needed to mechanically support patient respiration. A ventilator is used for anesthetized patients who cannot breathe on their own because they are paralyzed.

Oxygen outlets (hoses) are located on the walls at several places around the trauma bay (Figure 5-7(d)). These are used to oxygenate the patient either (1) by blowing oxygen directly to the patient's face, or (2) through an endotracheal (ET) tube under higher pressure or higher frequency.

Vital signs monitors

A trauma bay vital signs monitor is positioned in the back of the room, in the left corner (Figure 5-8(a)). The monitor displays the following information:

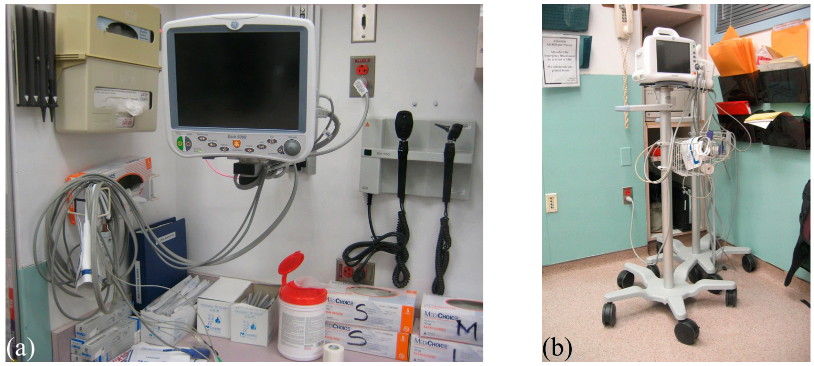


Figure 5-8: Vital signs monitors. (a) Trauma bay vital signs monitor. (b) Portable vital signs monitor.

1. Blood pressure and ECG waveforms
2. Pulse oximetry:
    a. Heart rate (pulse)
    b. Oxygen saturation (S_pO_2)
3. Respiratory rate

There is also a portable vital-sign monitor, wheeled on a cart (Figure 5-8(b)). When the patient is stabilized and readied for transfer to a CT scan facility or operating room, a switch is made from the trauma bay instruments to the portable ones. The portable vital signs monitor travels with the patient to the CT scan or other hospital units. This monitor is set up to check blood pressure automatically every 1–5 min. A technician is charged with performing the actual setup of the portable monitor.

Chest tubes and pleur-evac drainage equipment

Chest tubes are used for chest (thoracic) drainage (Figure 5-9). The patient may need a tube in their chest to drain air or blood from the intrapleural space (Figure 5-2). Pleur-evac systems are used to monitor the chest drainage by providing suction, patient pressure, and fluid collection data (Figure 5-9(b)). Equipment for inserting the chest tube is placed along the right wall in the trauma bay (Figure 5-6).

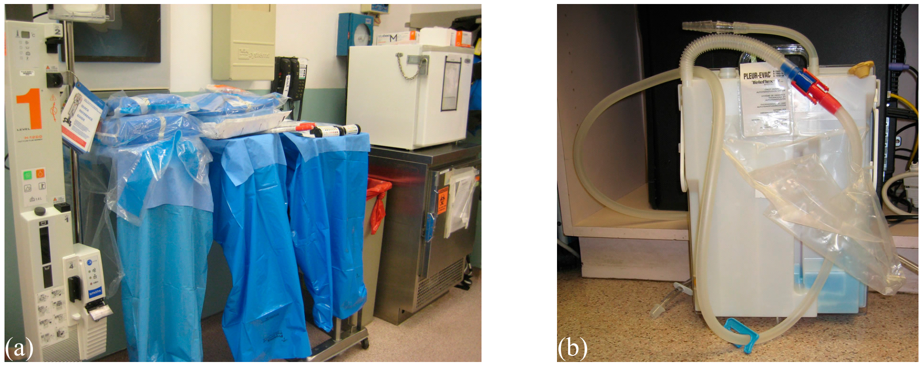


Figure 5-9: Chest-tube insertion equipment. (a) Chest tube trays. (b) Pleur-evac for chest drainage.

Intravenous (IV) catheters and fluid infusers

Access to the vascular system is obtained by the insertion of IV catheters. IV catheters are used for emergency administration of medications, fluid (crystalloids) or blood products. IV catheters vary in size. Adults typically receive a 16 or 18 gauge in their forearm, while infants and children receive smaller ones. A larger catheter may be placed if large blood loss or rapid fluid resuscitation is predicted for the procedure. The IV toolkit (Figure 5-10(a)) contains: catheter of appropriate size, IV set of tubing and bags, alcohol swabs, adhesive tape, adhesive dressing, and gauze. IV toolkits are placed on a shelf above the workbench, at the head of the stretcher (Figure 5-6).

Figure 5-10: Transfusion equipment. (a) Intravenous access toolkit. (b) Rapid fluid infuser (Level-1 infuser).

A rapid flow fluid warmer and infuser, also called Level-1 infuser, is used in the presence of massive hemorrhage (bleeding) and severe hypotension (Figure 5-10(b)). A Level-1 infuser is positioned along the right wall in the trauma bay, and is usually set up by the primary nurse.

Figure 5-11: Foley catheter tray.

Foley bladder catheter

Bladder catheterization allows for the assessment of urine (e.g., if there is blood in the urine) and for monitoring urinary output (Figure 5-11). A foley catheter tray is positioned on top of the chest tube equipment (Figure 5-9(a)). A foley is typically set up and inserted by the junior resident.

X-rays

The X-ray machine is located outside the trauma bay. When called for, the x-ray technicians wheel it in and take x-rays in the trauma bay (Figure 5-12(a)). Chest and pelvis x-rays are most common, but other can be ordered as well (e.g., x-rays of extremities if a bone fracture is suspected). The patient remains on the stretcher and the

Figure 5-12: X-ray equipment. (a) X-ray machine. (b) X-ray workstation for viewing x-ray images.

x-ray cassette is loaded into the stretcher. The trauma bay stretcher has a specially designed holder for an x-ray cassette. After taking x-rays in the trauma bay, a technician takes the cassettes to a radiology department where processing of the images takes place. Cassettes are read electronically. Information is brought up digitally, and viewed on an x-ray workstation in the trauma bay (Figure 5-12(b)).

Figure 5-13: FAST sonogram.

FAST and doppler

Focused Abdominal Sonogram for Trauma (FAST) is an ultrasound device used for a quick scan for bleeding in the upper abdomen (Figure 5-13).

Doppler sonography is used for ultrasound imaging of the cardiac pulse. This method is more sensitive than human fingers and can detect an impalpable pulse (e.g., in case the patient is suffering from a cardiovascular disease).

Broselow tape and wall charts

The Broselow Pediatric Emergency Tape is a tool to improve a child patient's weight estimation using established height-weight correlations (Shah et al., 2003). The tape along with its accessories provides the physicians with standardized, pre-calculated medication doses, dose delivery volumes, and equipment sizes using color-coded zones based on similar height-weight correlations. It is used as a lookup for how much fluid should be given and at what rate, based on a child patient's age (Figure 5-14(a)).

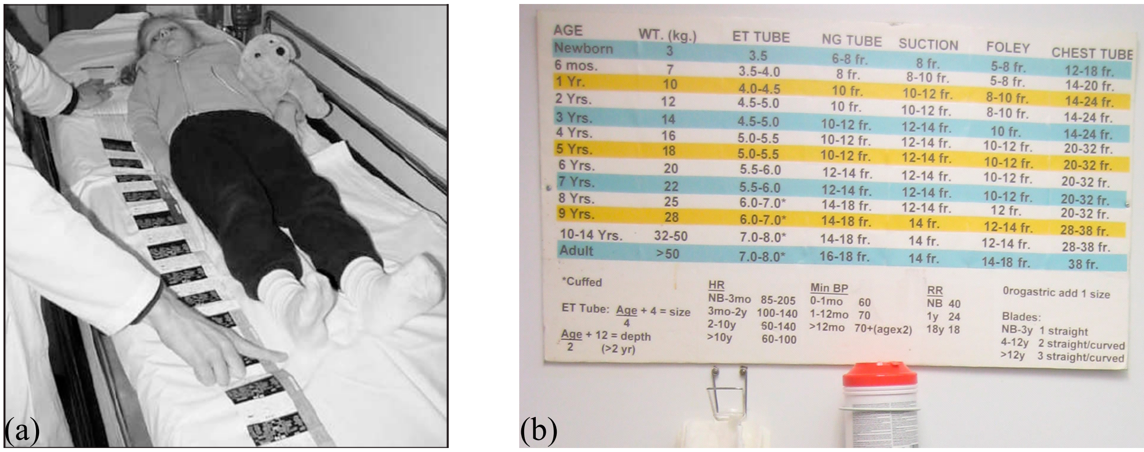


Figure 5-14: (a) The Broselow pediatric emergency tape (reproduced from Shah et al. 2003). (b) Wall chart showing treatment parameters.

Wall charts provide information on treatment parameters by patient age and weight, as well as the normal ranges of patient vitals, by age and weight (Figure 5-14(b)).

Patient temperature control

Room temperature can be easily elevated, since the patient can get cold quickly (Figure 5-15(a)). Several tools can be used to control the patient's temperature: a blood warmer device, a hot air blower, and a heat blanket (Figure 5-15(b)).

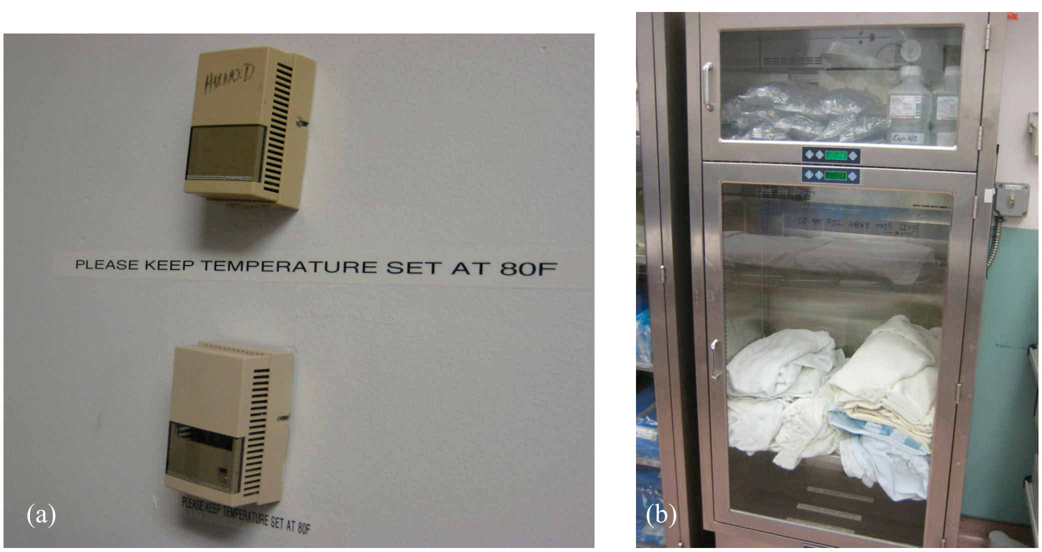


Figure 5-15: Temperature control. (a) Thermometer instrument. (b) Warm blankets.

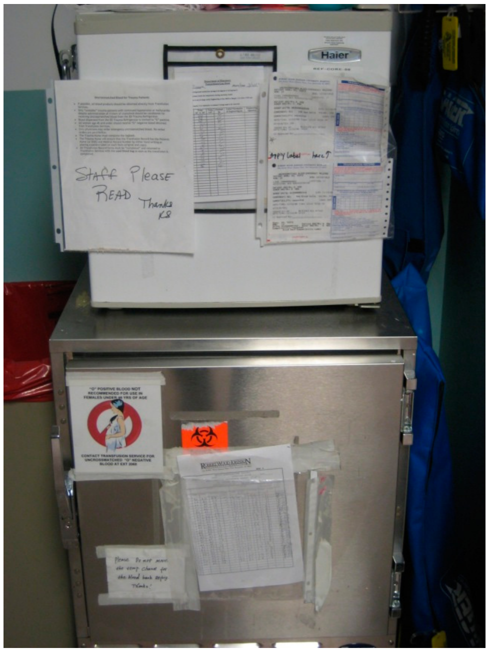


Figure 5-16: Refrigerator.

Refrigerator and medications cabinet

The refrigerator contains uncrossmatched, type “O-negative” blood and medications (Figure 5-16). Blood and narcotics are always locked in the refrigerator. There are two keys, one kept by a technician and the other one by the head nurse.

Other equipment

The glass-enclosed cabinet along the left wall in the trauma bay is filled with various instruments and equipment used for patient evaluation and treatment. For example, there are containers of sterile water for irrigation, scalpels, reserves of chest tube equipment, dressings, gauze, sponges, syringes, lines and tubes of various sizes, and bags of crystalloid solutions (Figure 5-17(a)). The trauma bay is also equipped with diagnostic tools for tests such as HemoCue, which is used for analyzing hemoglobin and glucose levels in blood. Wastebaskets can be found at several places across the room. These are used for disposal of used vials and implements. Physicians and residents carry stethoscopes (for chest auscultation) and trauma shears (for cutting the clothes). In short, the trauma bay is the best-equipped room in the hospital.

As can be seen from the above description of the trauma bay, the space of the trauma bay is tight, filled to capacity with equipment and instruments, and densely used. Upon arrival of the patient, the trauma team gathers rapidly around the patient’s stretcher, positioned in the center of the room. Each member has a prescribed position to start with,

Figure 5-17: (a) Glass-enclosed cabinet with equipment. (b) Instructions posted on the glass cabinet.

based on his or her role. The team leader stands at the top of the bed, while junior resident, orthopedic resident, nurses, and critical care technician assume bedside positions. The anesthesiologist and respiratory therapists normally stand next to the team leader, on his or her right side. The attending physician is positioned at the foot of the bed, while the nurse recorder stands behind a portable table located in the lower right corner of the room. This initial positioning of the trauma team reconfigures according to the needs of the patient. While all team members have a view of the patient, only some have a clear view of the various instruments in the trauma bay. For example, the positioning of the vital signs monitor requires the team leader to turn away from the patient to read his or her vital signs. Similarly, the positioning of the recorder's table makes it difficult to gather information on what interventions are occurring for documentation purposes.

There is a large variety of equipment that is kept in a non-standardized order. Medical personnel need rapid access to the equipment and sometimes have troubles finding it. Moreover, the equipment is complex and requires knowledge in order to use it. Although some instruction is provided through a variety of notes and guidelines hanging on the walls or on the cabinets, medical personnel need time to adjust to the arrangement of the trauma bay and learn how to operate the equipment (Figure 5-17(b)). This is especially problematic for personnel (e.g., nurses and residents) moving from one hospital to another, who are required to learn new equipment locations and interfaces every time they change their work place. Finally, the nature of the patient evaluation task often requires joint use of the equipment, which indicates a shared use of physical space.

5.7. Summary

This chapter reviewed results for the first research question obtained through the methods described in Chapter 4, as well as through the application of the cognitive work analysis approach. The initial section provided an overview of the trauma resuscitation domain, detailing different phases of the resuscitation, and describing the roles and tasks of trauma team members. This was followed by a detailed description of the trauma resuscitation goals, the process of summoning the trauma team and team composition. The final section described the trauma bay, a designated room in the emergency department for conducting trauma resuscitation. A description of the equipment and instruments used during patient evaluation was also included.

As seen from the results reported in this chapter, trauma resuscitation is a highly complex, socio-technical domain, with clearly defined goals and tasks. The goals are associated with the physiological systems of the patient's body and remain invariant for the duration of the resuscitation. The medical team performing the resuscitation consists of medical personnel with experience and specialized training in the management of critically injured patients, each with a predetermined role to carry out during trauma resuscitation. The initial team composition is always the same, i.e., everybody who is on call for the day assembles in the trauma bay. The team composition usually reconfigures during the resuscitation according to the needs of the patient. The trauma bay is equipped with a wide variety of instruments that are being used for patient evaluation and treatment. The equipment is complex to use and requires special knowledge for its operation.

The following chapter delves further into the characteristics of the trauma teamwork and the resuscitation process and reports results from the error analysis.

Chapter 6

Results

6.1. Chapter Overview and Purpose

The purpose of this chapter is to present the results from the analysis of trauma teamwork, information needs and the decision making process. For these results to be easier to grasp, it is useful to have an example or a representation of the activities of the various team members. To this end, the chapter starts with a narrative, presenting an example trauma resuscitation event. The example event is interesting because it highlights the challenges faced by trauma teams when evaluating patients with internal injuries not apparent on external examination. It involved a patient injured in a motorcycle accident, who sustained internal bleeding from a severe pelvic fracture, and who experienced bradycardia (heart rate drop) and hypotension during transport. The subsequent sections present various properties of team performance, including the tasks, role assignments, information exchange, communication practices, decision-making process and other findings. A simple model of trauma teamwork is presented at the end.

6.2. Narrative: An Example Event

The patient arrived by air and was brought to the trauma bay by the EMS paramedics, a junior resident, and the primary nurse. Because the initial report was given at the helipad to the present team members, the EMS crewmembers did not repeat the full report in the trauma bay. The EMS crew only helped transfer the patient from their stretcher to the trauma bay gurney and, soon after, started removing him from their portable vital signs monitor. The junior resident and the primary nurse started removing straps and clothes from the patient. One clinical care technician prepared the automatic blood pressure cuff, while another one placed the pulse oximeter on the patient's right finger and connected him to the trauma bay monitor. The team leader waited for the patient in the trauma bay and did not receive a report from the EMS crew on the helipad, as is customary. After gathering pieces of information and evaluating the patient for two minutes, the team leader asked, "*Can somebody please repeat the story!*" The junior resident who had heard the report on the helipad debriefed him: "*Adult male, motorcycle crash, initially hypertensive, BP 168 on scene, hypotensive in the 70s.*" The patient's heart rate (HR) and blood pressure (BP) dropped significantly during transport. The EMS crew was considering administering cardio-pulmonary resuscitation medications for a low HR and BP. Because they were close to the hospital, they postponed administration until arrival at the trauma bay. Upon arrival, the primary nurse stated out loud the medication names and handed syringes over to the EMS paramedic. He then passed them on to a second nurse to administer them.

After overhearing the medication names, the team leader asked the team when the last dose was administered. Without waiting for an answer, the leader proceeded with the evaluation and started examining the patient's chest using a stethoscope. Instead of giving a direct answer, the EMS paramedic started explaining why the patient needed these medications. The second nurse remained quiet, although it appeared that he was currently administering medications. At this time, the junior resident reported the patient's pulses, "*He's got distal pulses!*" and the team leader reported findings from his chest examination, "*I've got clear breath sounds!*" The team leader's comments later in the event showed that he believed (correctly) that the emergency medications had not been administered.

After examining lung sounds (step B) and pulses (step C), and obtaining the first BP and HR measurements (step C), the team leader moved on to the examination of pupils (step D), which is primarily used for identifying neurological injuries. Three minutes into the resuscitation, the team leader reported unequal pupils ("*Pupils dilated on the left, 4, on the right 2*") and continued with routine evaluation inquiring, "*Do we have x-ray here?*" At this time, the primary nurse was setting up an additional intravenous access and drawing blood, and the technicians were assisting with IV fluid administration. Several other team members inquired about the presence of the orthopedic surgeon who had not yet arrived at the trauma bay. The team's beepers sounded shortly thereafter, signaling that two additional trauma patients were arriving. Although in a hurry to obtain the needed x-rays, the team leader decided to wait until the primary nurse completed his tasks. Around six minutes into the event, the attending physician entered the room for the first time and asked for an update on the patient. The team leader summarized the EMS report and evaluation results, including the abnormal pupils finding. The room was noisy with several people speaking at once. The attending could not hear the team leader and had to ask for silence, "*Wait, there is too much noise!!! ... What's going on*?" The team leader repeated his report and exchanged a few questions with the attending. The team leader and attending decided to proceed with the primary survey and the patient was prepared for rolling to the side to evaluate for external injuries ('E').

The diagnosis of a pelvic fracture can be made by externally compressing the pelvis. When a pelvic fracture is observed or suspected, a rectal examination serves as a supplementary diagnostic step to corroborate this finding. Because the patient is turned to one side to evaluate for external injuries, a rectal examination is usually done in this step. The junior resident performed the rectal examination twice at about 8 minutes into the process but did not report the findings. The orthopedist arrived shortly thereafter, just as the team was ready to take x-rays. He examined the pelvis quickly, but also failed to report his findings. The team then recorded the x-rays and began preparing the patient for transport to the CAT scan. Seven minutes later, the patient was stabilized, switched to a portable vital signs monitor, and readied for transport to the CAT scan.

Suddenly, the patient's blood pressure dropped to a critical value. At this time, the team leader was focusing his attention on the patient's x-rays at a station in the corner of the room. The vital signs monitor sounded an audible alert signaling the patient's low blood pressure. This alarm, however, did not refocus the team's attention to the patient's changing status. The primary nurse and other helping nurses were occupied with inserting a nasogastric tube into the patient mouth. After a minute during which no team member responded to the auditory alarm, the respiratory therapist walked into the room, immediately noticed that the alarm was sounding and asked, "*Is he OK?*" The primary nurse approached the monitor, looked at it, and shouted, "*(expletive)!... 67 over 38! Open the fluid!*" The team leader was still focused on the patient's x-rays and did not immediately respond to this change. At this point, the attending physician came back from managing another trauma patient. The primary nurse now addressed the attending physician directly, "*BP 67 over 38 doc!*" The attending immediately started giving orders, "*Put him back on the regular monitor!*" The team leader eventually became aware of the change in patient status and assisted with direct patient care. The team was not able to diagnose the cause of the low blood pressure until pelvic x-rays showed a severe pelvic fracture that had led to internal bleeding. The presence of this injury and persistent hypotension prompted the team leader to order a blood transfusion. At 25′ 44″ after the arrival, the patient was transported to the radiology department for a CAT scan.

Although successful, the above trauma resuscitation revealed problematic aspects of treating severely injured patients. The team made several errors and failed to acknowledge and react to the potential signs of internal bleeding. The example also illustrates a number of properties of the team performance during trauma resuscitation. Sections 6.3 through 6.6 describe each problematic aspect in detail along with the properties of trauma teamwork.

6.3. Tasks and Role Assignments

Understanding who in the team does what task provided important insights into the division of physical and cognitive labor. This analysis also revealed the consistency of role assignments.

The results showed that individual control tasks were strongly associated with workers' roles even with variations in teams and resuscitation scenarios. To depict their work graphically, the frequency of task performance was averaged over different trauma teams confronted with 18 different resuscitations (Figure 6-1). It can be seen that the averaged matrix does not become uniformly gray. It, instead, retains dark peaks and empty regions. This constancy of the role-to-task relationship suggests that variations in distribution of control tasks across teams and resuscitations are minor despite the need for adaptation to different scenarios. For example, simple observation tasks such as instrument reading (IR) and manual measuring (MM) were done most commonly by technicians and nurses while more complex observations such as sensing and physical

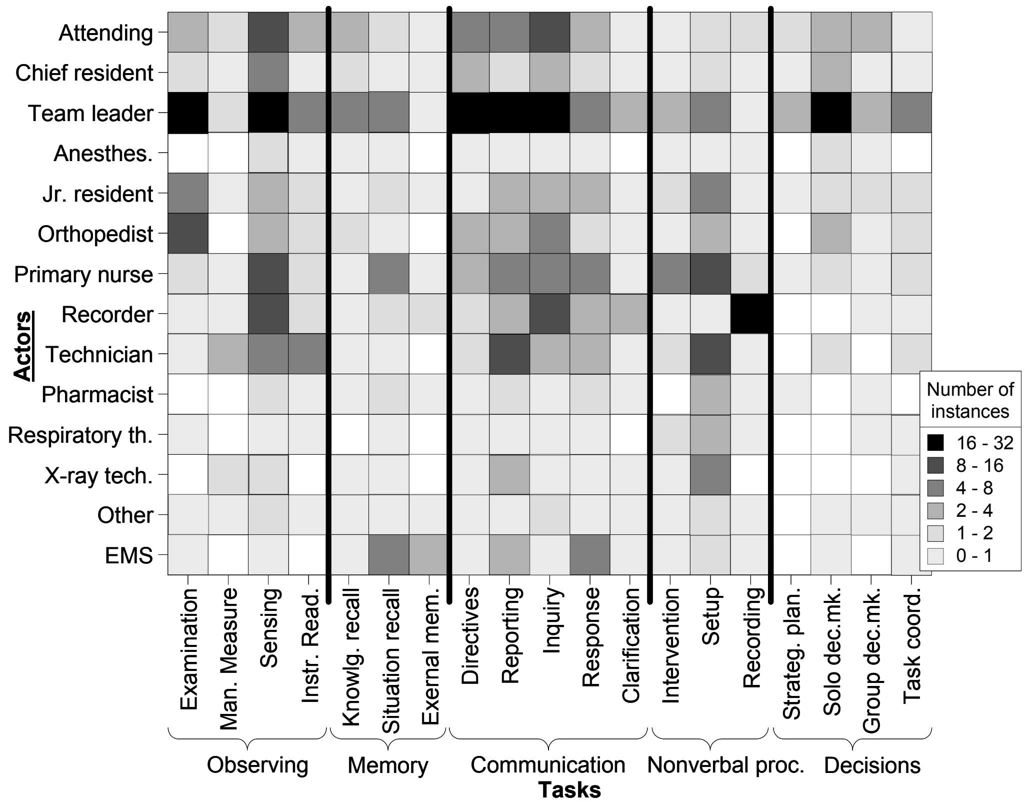


Figure 6-1: Frequency of control-task performance and communications averaged over 10 resuscitation events.

examination (SEN, EXM) were done by team leaders, attending physicians and residents. The decision making tasks were mainly done by team leaders and attending physicians.

Although there is no specific training for communication- and memory-lookup related tasks in the trauma protocol (unlike observing, deciding, and intervening), these tasks also exhibit consistency across roles and events. For example, most inquiries originated from team leaders, attending physicians and recorders. This observation may be explained by the fact that the leaders (physicians) needed up-to-date information to make decisions. In contrast, the recorder needed information to document the event. While the recorder's table was positioned to be out of the way of team activities (Figure 5-1), this factor created difficulties in information gathering, which often resulted in repeated inquiries. In an informal discussion with trauma team members following the

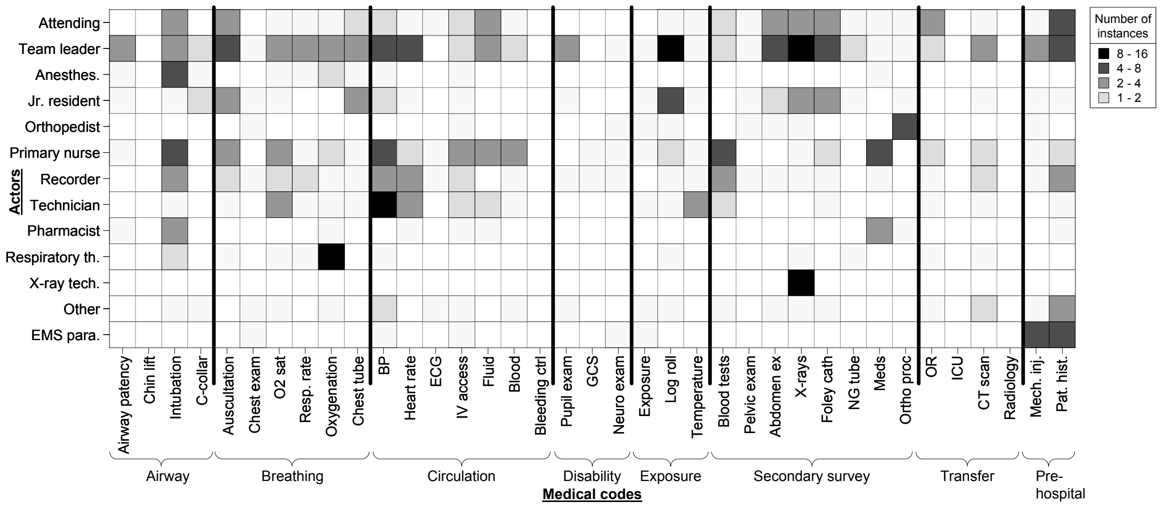


Figure 6-2: Frequency of medical task performance averaged over six actual resuscitations.

second simulation, the nurse recorder expressed frustration with the lack of anticipatory reporting, which made the documentation work difficult and prompted many unnecessary requests for information. Even when the vital signs were called out, most of the time only one or two vital signs were reported (blood pressure and heart rate, but rarely oxygen saturation or respiratory rate), which is a clear oversight. In two events, the recorder was observed moving the table closer to the patient bed, which enabled her to capture information more efficiently.

Most reporting was done by clinical care technicians, primary nurses and team leaders. A possible explanation for this finding is that supporting staff plays a crucial role in gathering patient information and communicating it to the rest of the team. The team leader coordinated the evaluation and treatment strategy based on received information, and reported assessments and decisions verbally to the team.

Role-to-task constancy is also observed for medical tasks (Figure 6-2). This constancy is not surprising because the care providers carried out the tasks and responsibilities associated with their roles. For example, chest auscultation was mainly done by the team leader, attending physician or junior resident; endotracheal intubation was always performed by an anesthesiologist with the assistance of a respiratory therapist; blood pressure and temperature were mostly measured by a technician while primary nurses set up intravenous (IV) lines and drew blood samples.

6.3.1. Observations

Patient evaluation in every trauma resuscitation starts with data gathering. Various team members gather patient information from the environment via physical examination, simple sensing, instrument reading and manual measurement. Several difficulties with access to information from the environment were observed in this study.

First, patient data is collected asynchronously. As team members observe various patient parameters, they report their findings to the decision maker, i.e., the team leader who mentally integrates the data and makes decisions. The problems occur when a team member does not report examination findings. Failure to propagate critical patient information results in team knowledge gaps and thus, poor data integration, which in turn affects decision making. As seen in the example narrative, the orthopedic and junior residents failed to report findings from pelvic and rectal examinations, respectively. Problems of this kind were observed in other resuscitation events as well:

> Resuscitation # 1:
> Team leader failed to report airway status
> Junior resident failed to report log roll findings
> Team leader failed to report findings from neck examination
> Junior resident failed to report findings from rectal examination
>
> Resuscitation # 2:
> Team leader failed to report findings from neurological exam (eye opening)
> Team leader failed to report findings from abdominal ultrasound (FAST) exam
>
> Resuscitation # 3:
> Junior resident failed to report log roll findings

Resuscitation # 4:
Junior resident failed to report log roll findings
Junior resident failed to report findings from rectal examination

Resuscitation # 5:
Team leader failed to report airway status
Junior resident failed to report radial and femoral pulses

Resuscitation # 6:
Team leader failed to report airway status

Resuscitation # 7:
Team leader failed to report airway status

Resuscitation # 8:
Team leader failed to report airway status
Junior resident failed to report findings from rectal examination

Resuscitation # 11:
Team leader failed to report airway status
Team leader failed to report findings from neurological exam (eye opening)

Resuscitation # 12:
Team leader failed to report findings from abdominal ultrasound (FAST) exam
Team leader failed to report findings on head injury

Resuscitation # 13:
Team leader failed to report findings from abdominal ultrasound (FAST) exam
Junior resident failed to report findings from rectal examination
Team leader failed to report findings from neurological exam (eye opening)

Resuscitation # 14:
Team leader failed to report airway status
Orthopedic resident failed to report radial and femoral pulses
Junior resident failed to report findings from rectal examination
Team leader failed to report findings on head injury

Resuscitation # 16:
Team leader failed to report airway status
Team leader failed to report findings from abdomen examination
Team leader failed to report findings from neurological exam (eye opening)
Junior resident failed to report radial and femoral pulses

Resuscitation # 17:
Team leader failed to report findings from abdominal ultrasound (FAST) exam

Resuscitation # 18:
Team leader failed to report airway status

Team leader failed to report findings from breath sounds examination

Unlike the example narrative, failures to report examination findings in other events did not result in near-miss errors. In most cases, unreported examination findings caused redundant inquiries or repeated exams. Nevertheless, the trauma surgeons on the research team considered these to be omission errors. Repeated exams can introduce delays in patient care, which can be fatal for unstable patients. For example, in resuscitation # 11, the team leader and junior resident performed a neurological exam about 5 minutes into the resuscitation. They asked the patient to squeeze hands and move extremities. Because they did not share their findings with the team, the orthopedic resident repeated the exam seven minutes later. Similarly, redundant questions can increase noise in the trauma bay, which can negatively affect team communications causing loss of information.

As explained by the trauma surgeons, findings about pupils, rectal tone, head injury, radial or femoral pulses and other patient parameters that were often unreported, can uncover key cues that the team can use to diagnose internal injuries early on. A key question is, then, why trauma team members do not report findings during the primary survey that can suggest a serious injury. In the example narrative, the team confirmed internal bleeding and localized it only after reviewing the x-rays (x-rays were taken at 10′ 13″ and available for viewing at 20′). One plausible explanation is that the primary survey in most resuscitation events reveals everything to be normal, leading the team to become conditioned to expect normal findings during this phase. The issue of missing multiple cues will be revisited in the following chapter, in Section 7.2.

Second, the vital signs monitor is positioned to be out of the way, which makes it difficult to view. For example, the team leader needs to turn away from the patient in order to read vital signs. In addition, current visualization techniques make it difficult for team members to perceive the information from distance. To sidestep this problem, a team member, usually a critical care technician (CCT) is assigned to read the vital signs monitor periodically and shout out the readings so others can hear them. The CCT occasionally forgets to report the vital signs, so other team members such as the primary nurse (PNR), may jump in and report. If no vital signs are reported for a longer period, a team leader, attending physician or nurse recorder may verbally prompt for their reading.

Failures to report vital signs were often observed throughout the study. Consider the following example from resuscitation # 2:

> At about 5 minutes into the evaluation, the patient's blood pressure (BP) is still unknown. The technician is trying to obtain automatic BP, but with no success. He decides to try measuring it manually. Two minutes later, the first BP is reported. The recorder is talking to an EMS paramedic and misses the report. The attending physician notices this and relays the message to the recorder, who finally acknowledges the value and writes it down. Shortly after, the technician reports new a BP value. It looks like the BP is dropping, and the attending physician relays this message to the recorder again. The team leader orders a bag of fluids to be administered. Five minutes later, the team leader requests a new BP value, "*Can we get another blood pressure?*" The technician responds, "*I'll give it to you right now!*" and starts measuring BP manually.

Notice that the technician needed a verbal reminder to obtain a new blood pressure measurement. This example confirms the fact that there is a lack of anticipatory reporting and that critical patient information often needs to be requested. Similar examples were observed in other resuscitations:

> Resuscitation # 8:
> The recorder inquires about vital signs two times throughout the event. The technician reported vital signs only once, at the beginning of the event.

Resuscitation # 9:
The technician reports first BP at about 2 minutes into the process. This is a partial report; it does not contain information about other vital signs, such as heart rate, oxygen saturation, and respiratory rate. A minute later, the team leader acknowledges the BP report and inquires about other vital signs: "*Alright, we got the heart rate?*"

Resuscitation # 10:
The technician reports vital signs only once, at about 4 minutes into the process. Four minutes later, the primary nurse checks the monitor and reports the vital signs directly to the recorder, without informing the rest of the team.

Resuscitation # 11:
The technician reports the first, full set of vitals at about 6 minutes into the process. The next set of vitals gets reported 7 minutes later after the recorder verbally prompted the technician to obtain new values: "*Can we get some more vitals!*"

Resuscitation # 12:
The technician is not reporting any vital signs. Instead of requesting this information, the recorder checks the vital signs herself. She approaches the vital signs monitor, reads out the values, and goes back to her table to writes them down.

Resuscitation # 14:
The technician reports vitals only three times throughout the event. The recorder does not inquire about vitals either.

Third, as seen in the example narrative, the entire trauma team failed to acknowledge the auditory alerts from the vital signs monitor for almost one minute, which is a critical delay for an unstable patient. This error can be classified as a fixation error (Reason, 1990)[1] potentially caused by habituation to sounds in the trauma bay or by a perception that the patient was stable and ready to move to the CAT scan. A similar problem was observed in the first simulation, in which the tone frequency increased (indicating an increase in the patient's heart rate), and the tone pitch decreased (indicating a decrease in blood oxygen saturation), but the team members did not notice this tone

[1] An error during which the workers are presented with considerable evidence that the system is not performing the intended action but continue to believe that they have correctly grasped the system state.

change. Delays in attending to audible alarms have been observed in other resuscitations, showing that this problem is common.

Finally, the observations needed for diagnosis are completed at different times, sometimes with many minutes between individual observations. Some observations, particularly physical examinations, have to be repeated to increase the certainty of the observation. In the example narrative, the findings needed to diagnose internal bleeding due to a severe pelvic fracture became available as follows: en route blood pressure drop; rectal exam results reported at 7′ 44″ into the resuscitation; pelvic rock exam performed at 8′ 30″ into the resuscitation; and a significant decrease in blood pressure, which happened at about 15 minutes into the resuscitation. Because of this temporal accumulation of data, the trauma team members must hold in their working memory the information about the observed symptoms until a diagnosis is made. To overcome the limitations of an individual's working memory, the team must rely heavily on transactive (collective) memory.

6.3.2. Memory recall and information retrieval

Quantitative data supported the argument that team members temporarily memorize and recall situational information. Most of the situation recall (see Situation recall column in Figure 6-1) occurred while workers were responding to questions. Supervisory team members mostly inquired about: what had been done (because they do not keep track of details such as the dosage or amount of medications and fluids given); how much time has passed since the last event (e.g., last blood-pressure measurement); and, for multi-step procedures, if steps have been completed or, if not, what was the current stage. Some examples of information types and actors involved in situation recall include:

- Team leader, answering the attending physician's inquiries about the mechanism of injury or treatments en route
- Anesthesiologist, specifying the tube size after endotracheal intubation
- Primary nurse, answering physicians' and recorder's questions about intravenous (IV) access or mechanism of injury
- Pharmacist, reporting on administered medications
- Various team members answering questions about the designated CAT scan room. Although announced earlier in the process, some workers still ask for this information
- EMS, reporting on the accident details, e.g., whether or not the patient was restrained by a seat belt.

External memory aids

As already mentioned, critical patient information is verbally conveyed to the recorder who maintains the trauma flowsheet, a form designed for documenting and archiving patient information and treatments. After the evaluation is completed, the flowsheet is transported with the patient and furnished to providers responsible for the patient's hospital care.

Limitations of the trauma flowsheet

There are several problems in keeping the trauma flowsheet current and complete: the late arrival of the nurse recorder, parallel activities (and reporting) of trauma team members, multitasking by the nurse recorder, the recorder's outlying position, and incomplete reports about examination findings.

In the following example, the nurse recorder arrived late to the trauma bay and missed the initial verbal report that was given by the emergency medical services (EMS) crew who transported the patient. This delay posed challenges in recording the pre-arrival information as well as initial patient-evaluation findings.

> As the EMS crew brings in the patient, the orthopedic resident asks if anyone is scribing. "*No*" is heard from the back of the room. One of the paramedics starts reporting pre-arrival patient information. The orthopedist repeats his question about the recorder but receives no answer. The attending physician quickly scribbles a few things on the trauma flowsheet and rushes to the patient side. The patient is transferred to trauma bay gurney and the team leader starts patient evaluation. The paramedic continues his report about patient injuries and treatments en route, while the team leader starts reporting initial evaluation findings. The orthopedic resident asks for the third time, "*Are we scribing anything?*" and several team members answer at once, "*No one is scribing!*" One minute later, the nurse recorder arrives and starts writing down information. The paramedic approaches the nurse recorder and repeats the pre-arrival information. The nurse recorder toggles between the flowsheet pages trying to capture information given simultaneously by the paramedic and the trauma team as they evaluate the patient and report their findings.

Problems caused by the recorder's late arrival were observed in four other resuscitations. Interview data with the nurses showed that the nurse recorder may be late when held up by other duties or when the patient arrives unexpectedly and no recorder is assigned in time. Because critical information about the patient is reported in the first 5-10 minutes of the patient encounter, the presence of the recorder from the beginning is essential. By arriving late, the recorder not only misses critical information, but also interferes with the ongoing care by trying to catch up and requesting information that has been already reported.

The second challenge to keeping the trauma flowsheet current and complete is parallel activities in the trauma teamwork. For example, while the team leader is examining the patient's airway, chest and lung sounds, the junior resident and orthopedist may start observing pulses and evaluating for fractures. Because of these simultaneous activities, findings by different team members often get reported at the same time. The following statement given by a nurse during the focus group discussion illustrates this problem:

> "… [Sometimes] it's just too much input. There needs to be an organized sequence in which the information is given, because there is one person who's the scribe for the trauma, and there are five or six team members … who potentially are giving information whether it's patient assessment information, the technician reporting the vital signs, the nurse saying where they just established an IV. So there is one person who's trying to write everything and there is five people giving that person information at the same time and if it's not given in an orderly fashion sort of… it's like you are all over the page…" (nurseGS)

To work around this problem, the nurse recorder often asked for information to be repeated. Sometimes, the recorder will leave his or her table to collect data themselves, moving more closely to the patient or even leaving the room to consult with a team member.

Third, although primarily dedicated to documenting trauma resuscitation, the nurse recorder may sometimes assist with patient care. The recorder may help the primary nurse with establishing intravenous access or drawing blood, or may temporarily leave the trauma bay to deliver blood samples for lab work. Although the primary nurse appreciates the recorder's multitasking, it introduces interruptions in the recording process and information loss. Consider the following excerpt from the field notes:

> The trauma team is about to start with the patient log roll, to assess for back injuries. The nurse recorder is at her table, busy with labeling blood samples that she has just received from the primary nurse. The team leader and junior resident start examining the patient's back and, at the same time, report the findings. The recorder is switching between labeling blood samples and writing down the reported information. The log roll is completed and the team prepares for taking x-rays. The recorder finishes the paperwork and announces to the team that she is taking the blood samples to the lab. After taking x-rays, the team leader and attending physician start with the ultrasound examination to check for abdominal bleeding. A minute later, they report findings, but no one records this information. The team continues assessing for other external injuries. Two minutes later, the

Figure 6-3: Information artifacts in trauma resuscitation. (a) Trauma flow sheet. (b) Whiteboard with pre-arrival information.

> primary nurse approaches the recorder's table, starts writing down the reported information and acting as the recorder.

Interruptions similar to this example were common and were mostly caused by the recorder’s multitasking. When the recorder temporarily left the trauma bay, another team member had to step in and continue with the recording. This role switching resulted in additional workload for team members who had taken on the new role.

Fourth, the recorder’s outlying position often prevented the recorder from hearing the examination findings or observing the activities in the trauma bay. To resolve this problem, the recorder moved his or her table closer to the patient area, or repeatedly inquired about the information until obtaining needed information.

Finally, team members often failed to report their findings or current activities. Patient’s medical history (existing allergies, medications, etc.) is an example of information that was often not reported to the team. It was observed that the team leader obtained this information directly from the patient (if conscious) or EMS paramedics, early in the evaluation, but failed to report it to others. This failure to disseminate resulted in repeated inquiries by the recorder and other team members, prompting them to obtain this information again directly from the patient.

Use of external memory aids

Although available during the resuscitation, artifacts such as the trauma flowsheet, the whiteboard outside the room, and the physicians' progress notes were only minimally used (Figure 6-3). The team members mostly relied on asking each other or the patient about important information throughout the event.

The data showed only a few instances in which team members looked up the flowsheet (External memory column in Figure 6-1) during resuscitations.

> Instance 1: Chief resident arrived late and inquired about the blood pressure. The team leader tried to recall the latest but failed. The recorder overheard them and read out the last reported blood pressure from the flowsheet:
>
> Chief (enters)
> Chief (talks to TEAM) *Do we have blood pressure yet?*
> Team leader (talks to Chief) *Yes we do, 190 something...*
> Recorder (looks at the flowsheet, talks to Chief) *191 over 78*.

The use of the trauma flowsheet was also observed towards the end of resuscitations when supervisory team members retrieved and examined images using the x-ray workstation:

> Instance 2: The leaders (Attending/Chief resident/Team leader) needed the patient's name to retrieve the x-rays. They approached and asked the recorder, who read it out from the flowsheet (patient name was initially obtained from the patient's driver license at the beginning of resuscitation):
>
> Attending (talks to Team leader) *Have we seen her x-rays or not?*
> Team leader (talks to Attending) *No, I didn't get a chance to look them up.*
> Team leader (approaches Recorder's table, talks to REC) *What's this patient name?*
> Recorder (looks at the flowsheet, talks to Team leader) *Jane Doe.*
> Team leader (talks to Recorder) *Jane Doe... thank you*.

To some extent, the trauma flowsheet also served as an information source at the end of trauma resuscitations when physicians on the team generated their progress notes. Progress notes typically contain information about patient medical history, and both critical patient parameters and treatments received en route and during the resuscitation.

However, rather than looking at the trauma flowsheet, physicians would often ask the recorder to read aloud information needed for their progress notes.

In contrast to the trauma flowsheet that helps teams externalize their cognitive processes to some extent, the whiteboard at the entrance to the trauma bay is rarely used. Pre-arrival information written on this board was observed only in a few cases. Even when completed, the whiteboard provided limited information and did not obviate the need for gathering additional information from team members who were present at the time of EMS briefing (Figure 6-3(b)).

Minimal use of external memory aids was also observed during information handover upon patient's arrival to the trauma bay. Information handover in trauma resuscitation is verbal and primarily relies on mental recall by the EMS crewmembers. Sometimes the EMS paramedics used notes that were handwritten on a scrap of paper to recall information from the field. Handwritten information mostly related to the treatments given en route (e.g., medications or fluids given) that require specific important details (e.g., dosing and time of administration) that might be difficult to remember. In two resuscitations EMS crewmembers were observed showing the nurse recorder images of the accident scene taken by their mobile phones. Interview data with the trauma surgeons revealed that physicians rarely trust photos from the accident scene. Because photographs are usually taken after patient extrication, the damages seen on the photographs are not from the collision but from the extrication. An interview with the EMS paramedic revealed that EMS crews believed that verbal reports were sufficient to convey important information about pre-hospital events. Although EMS crews had access to rugged portable PCs loaded with emsCharts software for archival documentation

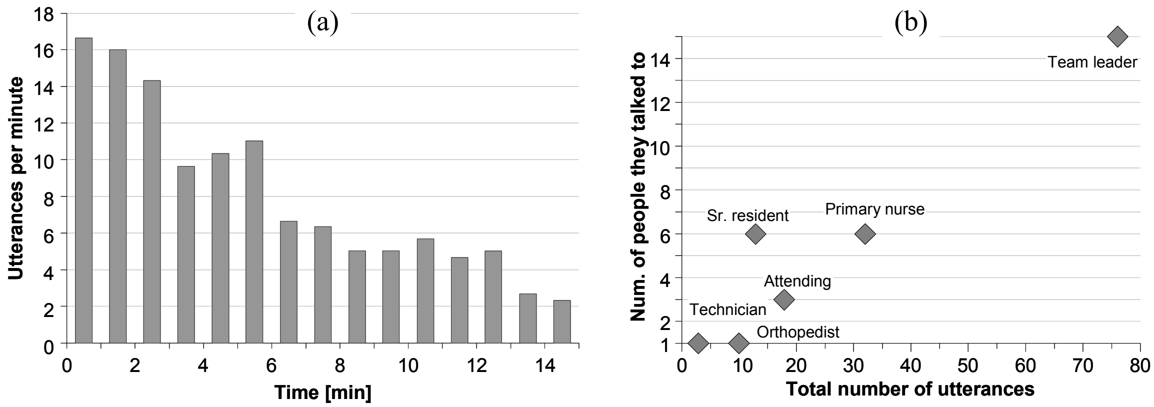


Figure 6-4: (a) Number of utterances per minute in a trauma resuscitation event. (b) Distribution of communication across team members.

purposes, these were not used during observed handovers. As one EMS paramedic reported, he is afraid of leaving it behind in the field: "*It's just another thing to carry and worry about. If I lose it, I am screwed for the day! My whole documentation work is gone!*"

6.3.3. Communication

During resuscitation, team members perform their prescribed tasks and report relevant patient findings, test results, and observations to other team members. Information exchange is between pairs, small groups, or within the entire team. Communication is largely spoken with only critical patient data and events recorded by hand on a trauma flowsheet.

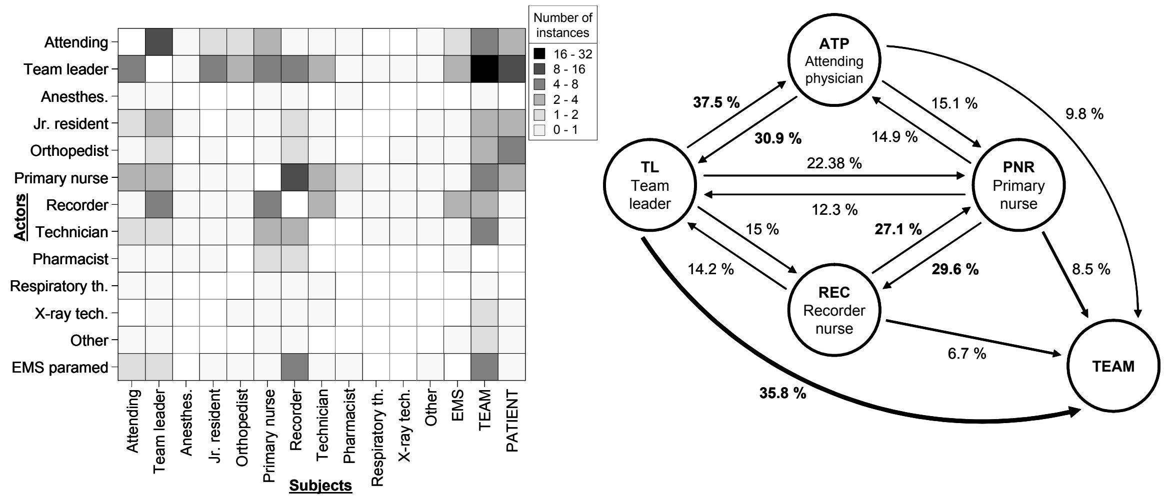
Despite its limitations, speech is a critical component of communication during trauma resuscitation. The team leader coordinates the evaluation and treatment strategy based on information received (via directives) and reports assessments and decisions verbally to the team. Due to the high level of channel noise, there is a loss of communicative exchanges. Currently, the problem is sidestepped by shouting, thus, adding to the high noise level. Occasionally, the team leader, the attending physician or the recorder may need to request silence as was seen in the example narrative. The patient status assessments and diagnoses made by the team leader are important for others to hear so they can prepare their tasks. However, this information is not always available or intelligible, and the team members need to ask for clarification (or, more dangerously, proceed with partial information). The following sections report the results obtained from the analysis of communication patterns in the trauma bay and highlight the most commonly observed communication problems.

Analysis of communication patterns

A graphical representation of communication output among team members is shown in Figure 6-4. The chart in Figure 6-4(a) shows how many times per minute somebody says something, averaged over three resuscitations. The number of utterances per minute declines throughout the resuscitation. During the early part of the resuscitation, someone is speaking every 4 seconds. The average utterance is 6 words long, but the length of each phrase ranges from one word ("yes", "okay") to as many as >60 words (e.g., a report from an EMS paramedic as the patient arrives at the hospital).

The nature of the communication in the room varies widely (Figure 6-4(b)). In the chart, the x-axis is the number of times a person spoke, and the y-axis is the number of different people spoken to. At one extreme, the team leader spoke 76 times to 15 different people; the primary nurse spoke 15 times but to only 6 different people. The patient was addressed 51 times but by only 3 of the team members. The EMS paramedics tend to speak frequently in the early stages of the resuscitation, but they talk mostly to the team leader. Some roles stand out: the team leader is clearly the focus of communications, speaking much more than anyone else and to a wider variety of team members.

An alternative representation of communication patterns among individual team members is shown in Figure 6-5. The graph in Figure 6-5(a) represents the "incidence



(a) (b)

Figure 6-5: (a) Frequency of communication among team members averaged over 18 resuscitation events. (b) Patterns of communication among key team members, extracted from (a).

matrix" of worker communications and reveals the team structure. In the matrix, the vertical axis shows who spoke, i.e., the actors, and the horizontal axis shows different people that were spoken to, i.e., subjects. It can be seen that the physicians (team leader, attending physician, and junior resident) most frequently address the entire team and other physicians and less frequently the nurses and technicians. Conversely, nurses and technicians most frequently address (collaborate with) other nurses and technicians and less frequently the entire team. Strong communication patterns can be seen between the team leader and the attending physician, as well as between the primary nurse and the recorder (Figure 6-5(b)).

Inquiries (Q) and reports (RP) appear to be the primary means of information sharing within trauma teams. The frequency of inquiries and reports was examined across 18 resuscitation events, and it was found that the average number of inquiries (55/resuscitation) exceeded that of reports (52/resuscitation). Previous work showed that most of the inquiries result from inefficiency in teamwork (Salas & Fiore, 2004), i.e., team members failed to anticipate others' information needs and did not communicate information unless asked. While it may be appealing to design technological support that will reduce the number of inquiries, attention needs to be paid to the basis for inquiries to avoid eliminating a potential key communication mode. The data showed that inquiries mostly came from the recorder (on average, 5 questions per resuscitation) who needed information to document the event (e.g., medications, treatments, vitals). The team leader, who asked 8.7 questions per resuscitation, needed frequent updates related to patient status. Similarly, the attending physician asked 4.6 questions per resuscitation, on average, to acquire information needed for monitoring the evaluation process. Team members who walked in late asked questions to obtain details about the patient history and the current status of the evaluation.

Communication problems

Failure to propagate information

A commonly observed error is failure to report critical patient information, such as examination findings. This type of error has already been discussed in Section 6.3.1. Trauma team members are required to report aloud the status of their activities, e.g., a completion of a specific task or a test finding. Reporting also helps the team maintain situation awareness about current activities in the trauma bay. A “failure to report” error can, thus, be classified as a communication error because it represents a failure to *propagate* information among team members, which results in a team’s incomplete situational awareness. Information can be lost not only in transmission but also if not reported. Propagating information makes it part of collective memory and increases the efficiency in decision making. It is important to understand why these errors happen in order to suggest efficient system designs that would facilitate information sharing in the trauma bay.

In addition to unreported examination findings and vital signs, team members often failed to propagate other types of information, such as patient medical history or treatments (e.g., administered medications). In the example narrative, the nurse who appeared to be administering emergency medications at the beginning of the resuscitation failed to report whether or not he administered the medications. This failure resulted in uncertainty about administration of the medications, which was not resolved until later in the resuscitation. The following examples from other resuscitation events illustrate that uncertainties and redundant questions caused by failures to propagate information are not uncommon:

> Resuscitation # 1:
> The team leader is considering administering antibiotics but first needs information about the patient's allergies. He obtains this information directly from the patient but does not share the findings with others in the team. The recorder also needs information about the patient allergies in order to document them in the flowsheet. A few minutes later, the recorder poses a question directly to the team leader, "*Did you ask about allergies?*" This prompted the team leader to report what he has just learned from the patient: "*Yes, no allergies, medications: (lists medications).*"
>
> Resuscitation # 4:
> The EMS crew attempted endotracheal intubation en route and administered a dose of a paralytic drug commonly used before this procedure. Upon the patient's arrival, the team leader asks the anesthesiologist to reattempt intubation. The anesthesiologist administers a new dose of the same medication without informing the team about her activities. The nurse recorder notices the pharmacist near the anesthesiologist and inquires: "*You guys medicate anything other right now?*" The pharmacist responds positively and reports the name and dosage of the medication.
>
> Resuscitation # 7:
> The patient medical history was not included in the EMS verbal report provided upon the patient's arrival to the trauma bay. This failure results in repeated questions coming from four different team members at different times throughout the event. First, the team leader obtains information about medical history directly

> from the patient, but does not report the findings. About ten minutes later, the junior resident approaches the patient with his progress notes and starts asking questions about his medical history. He, too, does not share the findings with others in the team. In the middle of the event, the primary nurse takes over the recording process and realizes that the patient medical history has not been recorded yet. He goes directly to the patient and asks about his allergies, past surgeries, and current medications. Shortly after, the team leader inquires again about the patient medical history, but this time she poses questions to the primary nurse. Finally, the orthopedic resident, needing the patient medical history for his progress notes, asks the team leader and junior resident about it.
>
> Resuscitation # 11:
> The primary nurse administers a tetanus shot at about 12 minutes into the evaluation process. He informs the patient about his activity, "*I am giving you a tetanus*" but fails to report this to the recorder. Towards the end of the event, at about 19 minutes, the junior resident and the primary nurse start discussing whether or not to administer a tetanus shot. It appears that the primary nurse does not remember that he already administered medication to the patient a few minutes ago. The team leader overhears the conversation between the junior and the nurse and orders a tetanus shot, "*Just give it to him.*" The primary nurse asks the patient if he went to school in New Jersey. After hearing the patient's response, the primary nurse concludes that the patient must have gotten the tetanus while in school and decides not to give another shot.

Repeated questions

Communication breakdowns can also occur when a team member provides a report about his or her current activity or an examination finding, but the person receiving the report may not hear or understand it. The most commonly observed problem of this kind related to discussions of the designated CAT scan room. There are two CAT scan rooms available in the Robert Wood Johnson University Hospital, one of which is called "the main room," and the other is referred to as "the secondary room." Towards the end of the resuscitation, a team member (usually the nurse recorder, primary nurse or junior resident) gives a phone call to the radiology department to announce the arrival of a trauma patient for a CAT scan. During this phone call, the caller learns which room is available and informs the trauma team via a brief verbal report, e.g., "*CAT scan's ready!*" or "*We are going to the main!*" The team members, however, may not always hear or register this information, which results in several repeated questions. For example, in resuscitation # 1, after reviewing x-ray images at about 16 minutes into the resuscitation, the chief resident announced that the patient was ready for the CAT scan. Upon hearing this announcement, the primary nurse picked up a phone and called the radiology department to secure a CAT scan room. A minute later, the technician inquired, "*What room are we going for CAT scan, main one?*" The primary nurse responded, "*The main!*" Shortly after, the team leader asked if anyone in the team called the CAT scan. The primary nurse responded that the radiology department had been contacted and the patient should be taken to the main room. Notice that the primary nurse did not inform the team about the designated CAT scan room, which caused several team members to repeatedly inquire about it. Similar instances of repeated questioning about the designated CAT scan room were observed in resuscitations # 2, 4, 7, 8, 10, 11, and 14.

Repeated questions were also common in situations when team members missed the initial EMS report about the patient's injury and then needed to inquire about it from other team members. These questions mostly came from the attending physician or the chief resident who often came in late. Instances of repeated questions related to the mechanism of injury were observed in resuscitations # 2, 5, 8, 9, 10, 12, 14, and 18.

Partial reports and partial orders

A different kind of communication breakdown occurs when a team member provides a partial report or gives a partial order. In the example narrative, the nurse recorder and the primary nurse got confused about medications that were administered en route partially because the initial EMS report did not include a list of all administered medications. Fortunately, the EMS paramedic was present in the bay when this information was needed, and he was able to respond to the nurses' inquiries. In the same resuscitation, the team leader ordered a blood transfusion at the end but did not specify the blood type, which prompted the primary nurse to clarify this order. Partial reports and orders mostly resulted in redundant questions and clarifications, and similarly to the cases with repeated questions, raised the level of noise in the trauma bay. Consider the following examples:

> Resuscitation # 1:
> *Partial order*: The primary nurse asks the team leader if he wants to give any antibiotics to the patient. The team leader answers, "*Yeah*" but does not elaborate on the type or dosage. At this moment, the attending physician interrupts by posing some evaluation questions to the team leader. The team leader starts answering those questions and forgets about his medication order. The primary nurse waits until the team leader finishes discussion with the attending and asks if he wants to give an antibiotic called ancef. The team leader answers positively but does not specify the dose.
>
> Resuscitation # 2:
> *Partial order*: At about eight minutes into the process, the technician obtains new blood pressure. It looks like the patient's blood pressure is dropping. The team leader orders fluids, "*Get her fluids going*" but does not specify the volume. The primary nurse clarifies if the team leader wants both fluid bags going or only one.
> *Partial report*: The technician reports the size of an IV access gauge to the nurse recorder but does not specify location. A few minutes later, the recorder asks the technician, "*Is the IV in the right or the left?*"
>
> Resuscitation # 3:
> *Partial order*: The anesthesiologist requests a paralytic medication. He needs these immediately to start with endotracheal intubation because the patient's airway is deteriorating. The pharmacist starts preparing medications but isn't fast enough because messages about the dosage go back and forth between the anesthesiologist, the primary nurse and the pharmacist. In this example, the anesthesiologist made an error because he didn't provide complete information when he ordered medications; the primary nurse had to ask about the dosage several times before she got the answer. Partial medication orders appeared to be the most common. Similar examples were observed in resuscitations # 7, 8, 12, and 17.

A more serious problem caused by a partial order occurs when the recipient of the message does not clarify information but proceeds with partial information. In resuscitation # 16, the team leader ordered antibiotics but did not specify the dosage. The recorder understood this request to be a standard dosage, which comes in two grams of the medication, and she asked the primary nurse to prepare two grams. The attending physician heard the recorder ordering two grams and corrected her saying, "*One gram is enough.*" Fortunately, the attending physician was present in the room and was able to prevent a possible overdose. Although one additional gram of antibiotics does not count as a near-miss error, similar situations could happen with a more serious drug (e.g. paralytics), resulting in adverse patient outcomes.

Unanswered questions

The analysis of communication exchanges showed that questions often go unanswered even when critical information is being sought resulting in yet another type of communication breakdown. As seen in the example narrative, the EMS paramedic did not answer the team leader's question about emergency medications directly and the second nurse did not answer at all. Despite the importance of the information, the team leader did not repeat his question. Several explanations may account for these observations. Although the paramedic heard the question and knew that medications had not been administered en route, it is possible that he did not know the status after he handed them to the second nurse. Conversely, the second nurse may have failed to answer because he did not know if the medications were already administered during transport. The nurse may also have missed the question because of parallel activities (e.g., transfer of the patient to the trauma stretcher, placement of the monitoring instruments, and the ongoing physical examination), people talking at the same time, or ambient noise. It is also possible that the nurse answered the team leader's question but used a signal not visible or audible in the video recording.

The analysis of questions posed by trauma team members across 18 resuscitation events revealed that 16% of all questions went unanswered. Most of these questions came from the team leader (28%), followed by the recorder (14%). Questions posed by the team leader related to the presence of other team members (e.g., "*Do we have anesthesia?*"), designated CAT scan room (e.g., "*Are we going to adult CAT scan?*"), patient vital signs (e.g., "*Do you have blood pressure on him?*"), and medications (e.g., "*You guys have propofol here?*"). Questions posed by the recorder mostly related to the evaluation findings (e.g., "*What about the lung sound?*") and vital signs (e.g., "*Do you have any vitals for me?*"). Further inspection showed that majority of these questions were asked during the peaks of activity, when several team members spoke at once or engaged in several parallel activities, which could potentially explain why those questions went unanswered.

Tracking multi-step procedures

There is a challenge of tracking the progress of multi-step procedures. As described in Chapter 5, a procedure is a sequence of actions carried out to accomplish a trauma resuscitation task. For example, the task of establishing an intravenous (IV) access is accomplished by carrying out the following procedure: (i) apply antiseptic to the skin area; (ii) insert the needle; (iii) slide the plastic cannula over the metal needle; (iv) remove the needle; (v) secure the cannula in place using tape.

Observational data and the analysis of communication exchanges showed that when multiple people are involved in carrying out a procedure, they have difficulty

Table 6-1: Example of repeated inquiries about the paralytic medication **etomidate** by the anesthesiologist over the period of three and a half minutes in event #3 (non-related lines are omitted). Role acronyms are as follows: ANST (anesthesiologist), PNR (primary nurse), PHARM (pharmacist), REC (nurse recorder), CCT (clinical care technician).

Line #	ACTOR	ACTION	SUBJECT	COMMUNICATION
236	ANST	((talks to	TEAM))	**Can we get some etomidate?!**
240	ANST	((while listing items, talks to	TEAM))	**Etomidate, need seven endotracheal tube, ...**
244	PNR	((approaches PHARM, talks to	PHARM))	Can you get me etomidate?
245	PNR	((approaches ANST, talks to	ANST))	How much etomidate?
247	PHARM	((starts preparing etomidate))		
267	ANST	((talks to	PHARM))	Pharmacy? Pharmacy? Pharmacy?
268	PHARM	((turns to	ANST))	(unintelligible)
270	ANST	((talks to	PHARM))	(orders succinylcholine)
271	REC	((talks to	ANST))	How much succinylcholine?
272	ANST	((talks to	REC))	(gives details about the amount)
274	PHARM	((stops with etomidate, starts preparing succinylcholine))		
277	ANST	((talks to	PHARM))	**You got etomidate with you?**
278	PHARM	((turns to ANST while preparing succs))	ANST))	(unintelligible)
279	ANST	((talks to	PHARM))	**(repeats specification about etomidate)**
284	PHARM	((hands medication to	PNR))	
285	PNR	((talks to	PHARM))	What is this?
286	PHARM	((talks to	PNR))	Succinylcholine.
289	PHARM	((goes back to refrigerator, continues preparing etomidate))		
298	ANST	((talks to	PHARM))	**You got the etomidate?**
299	PHARM	((talks to	ANST))	Yeah, I have it.
300	ANST	((talks to	PHARM))	(unintelligible) please!
322	ANST	((talks to	PNR))	Nurse, succinylcholine please! Succinylcholine!
323	PNR	((comes to patient's left side, talks to	ANST))	I am right here!
324	PNR	((administers succinylcholine via IV access))		
325	ANST	((talks to	PHARM))	**You got the etomidate?**
326	PHARM	((talks to	ANST))	Yeah, here it is.
327	ANST	((talks to	PHARM))	**She needs the etomidate real fast! Let's go!**
328	PHARM	((hands etomidate to	TECH))	
329	CCT	((hands etomidate to	PNR))	
330	PNR	((talks to	TEAM))	Succinylcholine given!
331	PNR	((takes the etomidate, administers it via IV access))		
334	PNR	((completes etomidate admin., talks to	TEAM))	Etomidate given!

tracking the progress of that procedure. In the example narrative, the team had difficulty monitoring the administration of emergency medications. In the case of administering a medication, there are several steps: it is ordered by a physician, prepared by a pharmacist, and given to a nurse who checks it for correctness, administers it, and reports that the medication has been administered. The team members had difficulty following which steps had already occurred and whether the medications had already been administered. Because team members needed to inquire each other about the steps that have or have not been completed, this difficulty in tracking the progress of a multi-step procedure also resulted in an increased amount of communication exchanges between the team members.

A similar example was observed in resuscitation # 3. The patient's airway started to deteriorate and the team decided to proceed with endotracheal intubation. The anesthesiologist ordered a medication called etomidate, which is needed to paralyze the patient while the intubation is being performed. The anesthesiologist needed the medication immediately and over the period of three and a half minutes, he inquired about it several times (Table 6-1). Notice that the anesthesiologist, shortly after ordering etomidate, ordered a different medication, called succinylcholine, which was also needed for intubation. A possible explanation for increased amount of communications and many repeated questions may be that the anesthesiologist was not sure where they were along the six steps required for administering both medications.

Problems with tracking the progress of preparing and administering medications were also observed in other resuscitations. Consider the following examples:

> Resuscitation # 8:
> The primary nurse, the nurse recorder and the pharmacist have difficulties tracking what medications have been administered and how much. The primary nurse believes they administered five milligrams of versed (tranquilizer), but the pharmacist corrects her, saying that they gave four milligrams. The medication was ordered two times, and each time two milligrams were administered.
>
> Resuscitation # 14:
> The team leader orders two grams of ancef (antibiotic) just before taking the x-rays. Everybody leaves the room so that x-rays can be taken. Upon her return to the room, the primary nurse clarifies the amount of ancef with the attending physician, who is now ordering one gram. The primary nurse prepares the medication and administers it, without reporting the dosage. A few minutes later, the nurse recorder documents administered medications in the trauma flowsheet and writes down two grams of ancef. The recorder did not hear the attending changing the order to one gram. The primary nurse explains that only one gram has been administered because the attending physician ordered so.

Resuscitation # 17:
The pharmacist has difficulty tracking what medications have been administered as he is trying to report medications to the nurse recorder. The team leader and the attending were changing their decisions at the time of ordering them. First, the team leader ordered a medication called diprovan, but the attending disagreed and said that they cannot give it because it will cause problems for the patient. Later, the team leader insisted that they give diprovan, but the attending disagreed again. In the meantime, the attending physician ordered versed as a substitute for diprovan. Shortly after, the team leader also ordered ancef (antibiotic) and tetanus.

Another multi-step procedure that requires monitoring is the administration of intravenous fluid. This procedure consists of the following steps: ordering fluid, retrieving the bag of fluid from the cabinet, setting up the bag, starting up fluid, and periodic monitoring. Difficulty with tracking fluid administration was observed in most resuscitations including the example narrative, as shown in the following excerpt from the transcript:

Attending	(enters room, talks to TEAM) *Fluids running wide in?*
Nurse2	(talks to Attending) *Yes.*
Attending	(talks to TEAM) *How many IVs?*
Nurse2	(talks to Attending) *He's got three IVs, two 16 and an 18.*
Attending	(talks to TEAM) *And fluids run through all of them?*
Nurse2	(talks to Attending) *Ah, I am just getting fluids for the third one and I'll hang it right now for you.*
Nurse3	(hands a fluid bag to, talks to Technician) *Hang it up there.*
Attending	(talks to TEAM) *Have we given any meds?*
Nurse3	(talks to Attending) *No meds have been given, that's why they didn't give anything…*
Technician	(talks to TEAM) *BP 71 over 41!*
Attending	(talks to TEAM) *How much fluids running in total?*
Nurse2	(pumps the bag, counts bags, talks to Attending) *One, two, three, four, 2 liters... I've got one down over there... 2 liters so far, we're working on 5*

Similarly to tracking the types and amount of medications that have been administered, the administration of fluids requires team members to monitor the amount of fluid that has gone into the patient. To accomplish this task, team members inquire each other about completed steps, thus increasing the number of communication exchanges.

6.3.4. Decision making

The analysis of decision-making tasks showed that trauma teams mostly engage in rule-based behaviors, on average, 37 per resuscitation. The distribution of these behaviors is shown in “solo decision making” and “strategic planning” columns in Figure 6-1. Team members who engaged in these behaviors included the team leader, the attending physician, the chief resident (when present), and other physicians (e.g., anesthesiologist, orthopedic resident). Skill-based behaviors during trauma resuscitation were frequent but mostly applied individually and rarely collaboratively. The distribution of skill-based behaviors is shown in “task coordination” column in Figure 6-1, on average, 5 per resuscitation. Task coordination was mostly performed during patient transfer from one stretcher to another, or during log roll, i.e., when the patient is turned on the side for examination of back injuries. Although collaborative, knowledge-based behaviors occurred rarely, on average, 5 per resuscitation. The distribution of these behaviors is shown in “group decision making” column in Figure 6-1. Further investigation into knowledge-based behaviors showed relatively few collaborative problem-solving activities. This observation may be surprising because trauma teams face complex problems that, one would predict, require consultation of several team members and consensus building. Research has shown that critical decision-making in trauma teams is mostly concentrated in the current leader’s role (Klein et al., 2006). The results of this study support this previous finding as it was observed that the physician in charge made most decisions and rarely consulted others.

A few cases of group decision-making that were observed showed that the supervisory team members engaged in collaborative problem solving during discussions of examinations, such as the abdomen ultrasound exam for internal bleeding (FAST), administration of medications, and review of x-rays. The example below shows supervisory team members deciding on ordering a CT scan based on x-rays results:

Junior	(talks to Team leader) *We'll do abs CT, head, spine?*
Team leader	(approaches x-ray workstation)
Team leader	(talks to Junior) *Don't know yet. We'll decide once we get the chest x-ray.*
Team leader	(at the x-ray workstation, waits for x-ray images)
Attending	(approaches x-ray workstation)
Team leader	(examines x-rays, talks to Attending) *This actually looks okay. May be we could just CT the c-spine?*
Attending	(points to the screen, talks to Team leader) *I would go for a full CT.*
Junior	(joins Attending and Team leader as they discuss x-rays)
Team leader	(talks to Junior) We'll get the CT of head, spine, abdomen, pelvis, and c-spine.

6.4. Parallel Activities

Perhaps the most salient property of trauma teamwork is that the activities of the team members take place in parallel.

While ATLS protocol is conceptually conceived and taught as a hierarchically ordered process, each step may be repeated as patient status changes or more information becomes available. The work done by the team involves a great deal of parallelism. For example, the primary nurse can start setting up the intravenous (IV) access immediately upon patient arrival without a specific direction from the team leader. At the same time, the team leader may start with the chest examination (part of step B), and the orthopedic surgeon may start his assessment for fractures (part of secondary survey). The ATLS protocol does not specify team members’ responsibilities but instead imposes a framework that the team should follow.

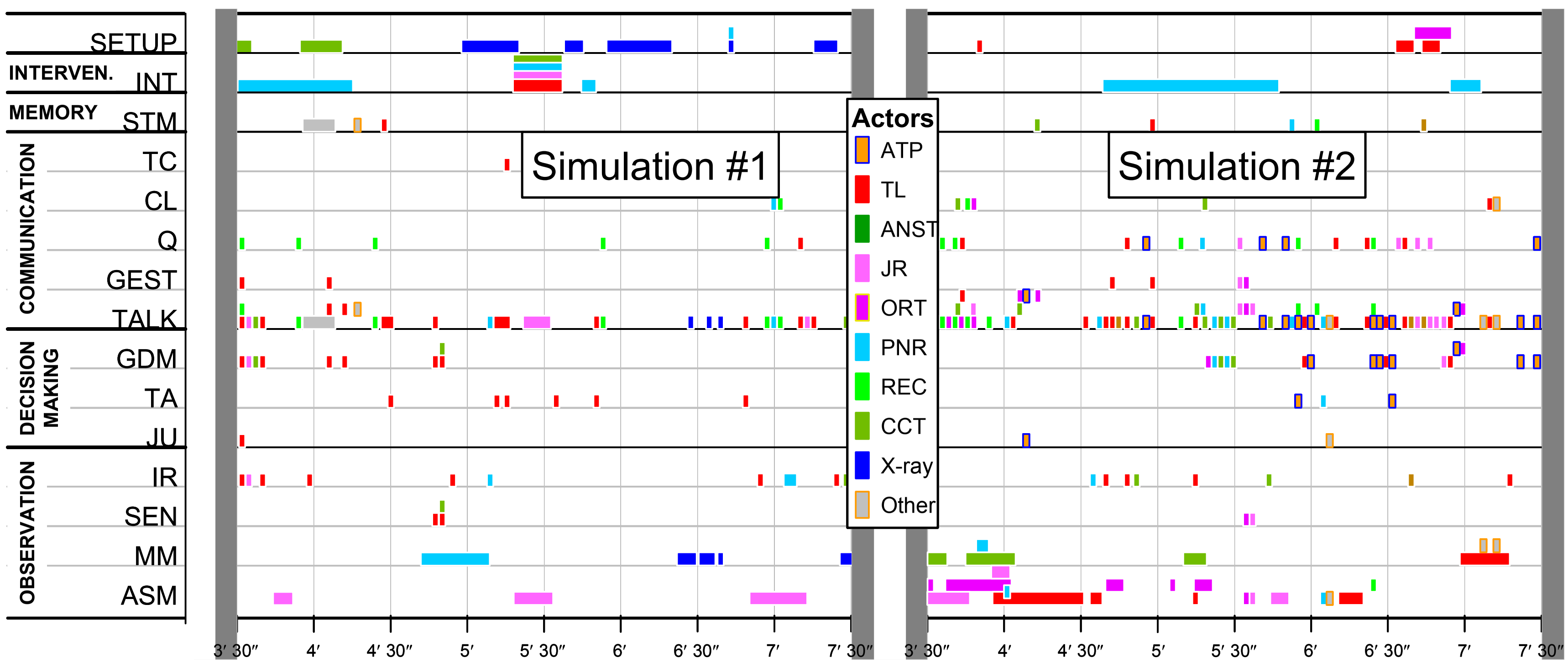


Figure 6-6: Segments of temporal activity diagrams between 3 ′30″ – 7′30″ minutes of two simulated resuscitations. The bar color represents the actor who performed the task and the bar length indicates the task execution time.

To avoid performance of redundant tasks, most trauma centers have specified the roles and responsibilities of team members allowing only limited variation. Because it deals with prioritization of evaluation tasks and a description of treatment procedures, the ATLS protocol is patient- or problem-centric, rather than team-centric.

A temporal analysis of each team's activities in two simulated resuscitations showed variations in task performance and sequence (Figure 6-6). The observed differences often did not represent errors in following the ATLS protocol, but rather acceptable variations within its framework. For example, the task of establishing intravenous access, which is included as a part of ensuring adequate perfusion ('C'), was performed in parallel with the chest examination, which is a step for evaluating the adequacy of ventilation ('B'). Variations of this kind were chosen based on the patient's injuries, the team's experience and composition, or the team leader's skills. Similar findings have been observed by others (Klein et al., 2006). While variations in the order of specific tasks may not contribute to adverse patient outcomes, deviation from the management and treatment goals of ATLS have been shown to have an adverse effect (Clarke et al., 2000; Gruen et al., 2006).

Although common during trauma resuscitation, parallel activities can cause problems. The problems occur when several team members perform their activities over a shared resource, e.g., the same body part. In the example narrative, the primary nurse started drawing blood samples while the team leader wanted to take x-rays. The team leader decided to hold until the primary nurse completed the blood draw. In resuscitation # 17, the orthopedic resident repeatedly lifted the patient's arm while the team leader was working on chest tube insertion on the same side. This interference prompted the attending physician to step in and ask the orthopedist to defer his examination to a later time. Similar examples were observed in other resuscitations. Consider the following examples:

> Resuscitation # 3:
> The technician has difficulties with placing the automatic blood pressure cuff because the primary nurse starts the blood draw immediately upon the patient's arrival. This collision over a shared resource (i.e., the patient's right arm) results in a delayed blood pressure measurement.
>
> Resuscitation # 5:
> 1. The orthopedic resident performs a pelvic exam by externally compressing the pelvis while the team leader is listening to the patient's breath sounds. The team leader stops listening to breath sounds and resumes shortly after the orthopedic resident finishes the pelvic exam.
>
> 2. The primary nurse starts a blood draw and IV setup a minute before the team leader orders a patient log roll. The team waits for the nurse to finish the blood draw before starting with the log roll.
>
> Resuscitation # 6:
> The primary nurse starts a blood draw while the team leader is examining the radial pulses on the patient's arms. The log roll is also delayed to accommodate the primary nurse.
>
> Resuscitation # 7:
> 1. The orthopedic resident performs a pelvic exam by externally compressing the pelvis while the team leader is listening to the patient's breath sounds. The team leader stops listening to breath sounds and resumes shortly after the orthopedic resident finishes the pelvic exam.
>
> 2. The primary nurse starts a blood draw while the team leader is performing the primary survey. The log roll is delayed to accommodate the primary nurse.
>
> Resuscitation # 9:
> The primary nurse starts a blood draw while the team leader is examining the radial pulses on the patient's arms. The attending physician asks the primary nurse to stop with her activity and continue after the team takes the x-rays.
>
> Resuscitation # 11:
> The primary nurse starts a blood draw immediately upon the patient's arrival. The technician waits for the nurse to finish her task in order to place the automatic blood pressure cuff.

Table 6-2: Examples of the information needs of the core trauma team during different phases of resuscitation.

Actor / Phase	TEAM LEADER	ATTENDING PHYSICIAN	RECORDER NURSE	PRIMARY NURSE
Phase 0: Before Patient Arrival	* Time of patient arrival * Severity of injury * Status during transport * Patient age	* Time of patient arrival * Urgency * Availability of trauma team * Status during transport	* Time of patient arrival * Status during transport * Patient age	* Time of patient arrival * Mechanism of injury * Number of patients * Means of transport * Patient age
Phase 1: Upon Patient Arrival	* Details of injury mechanism * Updated status * Allergies	* Nature of injury	* Updated status * Details of injury mechanism	* Updated status * Details of injury mechanism
Phase 2: Primary Survey	* Vital signs * Airway patency * Breath sound status * Pupils * Neurological status	* Vital signs * Overall overview of situation	* Vital signs * Airway patency * Breath sound status * Pupils * Neurological status	* Vital signs * Volume of fluid needed * Size of IV gauges * Blood tests to draw * Size of airway
Phase 3: Secondary Survey	* Need for additional tests	* Need for additional tests	* ED disposition * Types of additional tests	* ED disposition * Types of additional tests

Resuscitation # 14:
The primary nurse starts a blood draw while the team leader is performing the primary survey. The attending physician asks the primary nurse to stop the blood draw and continue with it after the team takes the x-rays.

Resuscitation # 16:
The orthopedic resident perform a pelvic exam while the EMS paramedic is still reporting the details about the accident and the team is un-strapping the patient. The orthopedic resident is in the way and the nurses have to step aside to let the orthopedic resident complete his exam.

6.5. Information Needs in Trauma Resuscitation

Trauma teams manage large amounts of information about patient status and the team's current activities over the course of trauma resuscitation. This information becomes available in a short time period (<20-30 minutes) and in a continuous data flow from sources both inside and outside the hospital. Not all of this information is equally complex nor it is needed at all times.

Table 6-3: Number of questions and duration for each trauma event.

Event #	Number of questions (*n*=982)	Approx. event length (min)
1	54	~ 22
2	47	~ 26
3	51	~ 26
4	98	~ 25
5	52	~ 21
6	40	~ 20
7	54	~ 32
8	34	~ 22
9	39	~ 19
10	112	~ 21
11	55	~ 23
12	35	~ 20
13	41	~ 17
14	48	~ 22
15	46	~ 24
16	45	~ 23
17	93	~ 47
18	38	~ 37

Results from interviews and focus groups showed the basic information needs of each role (Table 6-2). While some specific information needs were shared across all roles, the overall needs of each role were distinct. For example, the attending physicians needed an overview of the situation in the trauma bay, while the team leader and nurses needed more specific information about the patient status throughout the resuscitation.

An analysis of inquires and responses extracted from the transcripts verified the results about information needs revealed through interviews and focus groups. A total of 982 questions (54.5 ± 22.6 questions [mean ± SD]) were identified in 18 trauma resuscitations. No correlation was observed between the number of questions and the duration of a resuscitation (Table 6-3).

An analysis of inquiries revealed 16 major categories with over 80 types of information needed in a typical resuscitation (Table 6-4). Most questions related to the patient evaluation and were aligned with the steps of the ATLS protocol. This finding is consistent with the principal task of trauma resuscitation—continuous reevaluation of patient status and monitoring for any changes in patient status. Ongoing monitoring of events represents the second largest general grouping of questions and includes questions about vital signs, medications and fluids given. Two categories of questions unique to trauma resuscitation related to the mechanism of injury and pre-hospital treatments.

Table 6-4: Categories of questions asked by trauma team members, in a descending order by the number of questions.

Question category	Description	Questions (*n* = 982) 100%	Examples
Evaluation	Assessment of airway, breathing, circulation, neurological status, and other injuries; findings and status change	292 (30%)	Did you assess the airway? Do you have any pulses in the lower extremities? Do we have any spontaneous eye openings?
Patient medical history	Medications, allergies, surgeries, past illnesses, habits, hospitalization…	92 (9%)	Any known allergies? Do you take any medications?
Medications	Dosage, rate, type, administration, timing…	88 (9%)	How much is the Propofol running at now?
Vital signs	Blood pressure, heart rate, oxygen saturation, temperature, respiratory rate	67 (7%)	Do you have any vitals for me? Do we have blood pressure yet? Heart rate?
Team members / Personnel	Presence, coordination, readiness, identification…	64 (7%)	Do we have anesthesia? Ready to go? Who's going to take the ventilator?
Patient personal information	Age, gender, date of birth, profession…	49 (5%)	Do you have name on him? What kind of work you do?
Equipment	Status, handling, tracking…	49 (5%)	Anybody has blood warmer? ET tube size?
Mechanism of injury	Details about the accident	48 (5%)	What's the story? Okay, what did we get? Who know the story for this patient?
Transfer	Preparing for CAT scan or operating room	40 (4%)	What room are we going for CAT scan?
Miscellaneous	Unable to fit to any of the categories	38 (4%)	You [team member] alright? Do you have a pen?
IV access	Specifics, location, status, number…	33 (3%)	What's the IV access? Where is the IV?
Pre-hospital treatments	Questions about patient status, treatments, medications, and vitals en route	32 (3%)	How was her airway in transport? What were his scene vital signs?
Plan of care	Treatments, interventions, and effects	32 (3%)	Are we going to intubate her?
Administrative	Order placement, paperwork, extrication time, date…	23 (2%)	Do you want me to put orders for you? Do I need to sign anywhere?
Teaching	Teaching and monitoring questions	19 (2%)	You've done ABC? What about the D part?
Fluids	Type, amount, status, rate	16 (2%)	Is she getting fluid 125/hour?

These aspects of trauma care are important for preparing the team before patient arrival and planning anticipated care.

Questions about pre-hospital care

Further analysis of questions posed during trauma resuscitation revealed that questions about pre-hospital care comprised a significant fraction of all questions asked by trauma teams. The key categories that emerged from the analysis of questions posed to EMS crewmembers are shown in Table 6-5, while categories of questions asked among the trauma team members are shown in Table 6-6. Analysis of these questions provided an insight into the trauma teams knowledge gaps caused by incomplete, missed, or forgotten EMS reports. By looking at the types of information requested and the time the request happened (during or after information handover), insights into where the gaps in the information needs are and when they occur were obtained.

Table 6-5: Questions posed by trauma team members to EMS crews during or after the patient handover.

Question type	# questions	# events
Mechanism of injury, details	19	8
Patient demographics (name/birthdate)	12 (8 / 4)	9
Event summary	9	7
Vascular access points (num/loc/size)	9 (6 / 2 / 1)	7
Vitals (at scene/en route)	6 (4 / 2)	5
Mental status or loss of consciousness	5	5
Medications en route	3	3
Fluids	3	3
Patient info (address/phone/belongings)	3 (1 / 1 / 1)	3
Medical history (summary/allergies/meds)	2 (0 / 2 / 0)	2
Treatments en route	2	2
Transport details	2	2
Airway status en route	1	1
Sustained injuries	1	1

The trauma teams asked the EMS crews 77 questions in 18 resuscitations (4.3 ± 2.8 questions per resuscitation [mean ± SD]). Additionally, there were 58 questions about prehospital care among the trauma team members after the EMS crew left (3.2 ± 2.6 questions per resuscitation). Given the large amount of information types typically reported by EMS paramedics, the relatively high overall number of questions (7.5 ± 5.4 questions per resuscitation) indicates incomplete handovers and low retention of information. The lack of some items in Table 6-6 and different relative frequencies compared to Table 6-5 reflect the changing information needs of trauma teams as resuscitations are progressing.

Table 6-6: Questions among trauma team members about pre-hospital care after EMS crews left.

Question type	# questions	# events
Vascular access points (num/loc/size)	18 (14 / 3 / 1)	12
Med. history (summary/allergies/meds)	10 (3 / 3 / 4)	7
Patient demographics (name/birthdate)	9 (9 / 0)	5
Mechanism of injury, details	5	4
Event summary	5	4
Treatments en route	3	3
Medications en route	2	2
Mental status or loss of consciousness	2	2
Patient info (address/phone/belongings)	2 (0 / 0 / 2)	2
Vitals (at scene/en route)	2 (0 / 2)	1

It is also interesting that questions about pre-hospital care comprised a significant fraction of all questions asked by trauma teams. There were 714 questions in 18 resuscitations (excluding questions to patients). Of these, 135 (19%) were about pre-hospital care information. In other words, every fifth question was about pre-hospital care, which shows the importance of this information to trauma teams.

Most questions posed to EMS crews were about the details of the mechanism of injury (19 overall). Of these questions, most were asked after the EMS crewmembers finished their initial report (14 questions [74%]), while the remaining questions were asked during the report. The questions asked after the EMS reports were focused on obtaining additional details about the mechanism of injury. For example, in one resuscitation, the patient suffered a fall and team members' inquired about whether the patient jumped or slipped and from what height. In five out of 18 resuscitations, the recorder arrived after the initial EMS report and requested injury details directly from the EMS crewmember.

Critical information that was often omitted in the EMS reports related to intravenous (IV) access, patient name, and medications. Patient name was omitted in seven resuscitations and the team needed to request this information both during and after the handover. EMS crews often failed to report details about mental status, IV access and medications that were given. For example, the EMS crew was often observed giving only the name of a medication but skipping the dosage or timing. Because some medications require strict timing, failure to report the timing of the last dose can have important implications for patient care.

Most questions posed after the EMS crew left the trauma bay were about the details of IV access, patient medical history, and demographic information. Answers to these questions were provided either by team members who remembered this information from the EMS reports, or by the recorder who looked them up from the flow sheet.

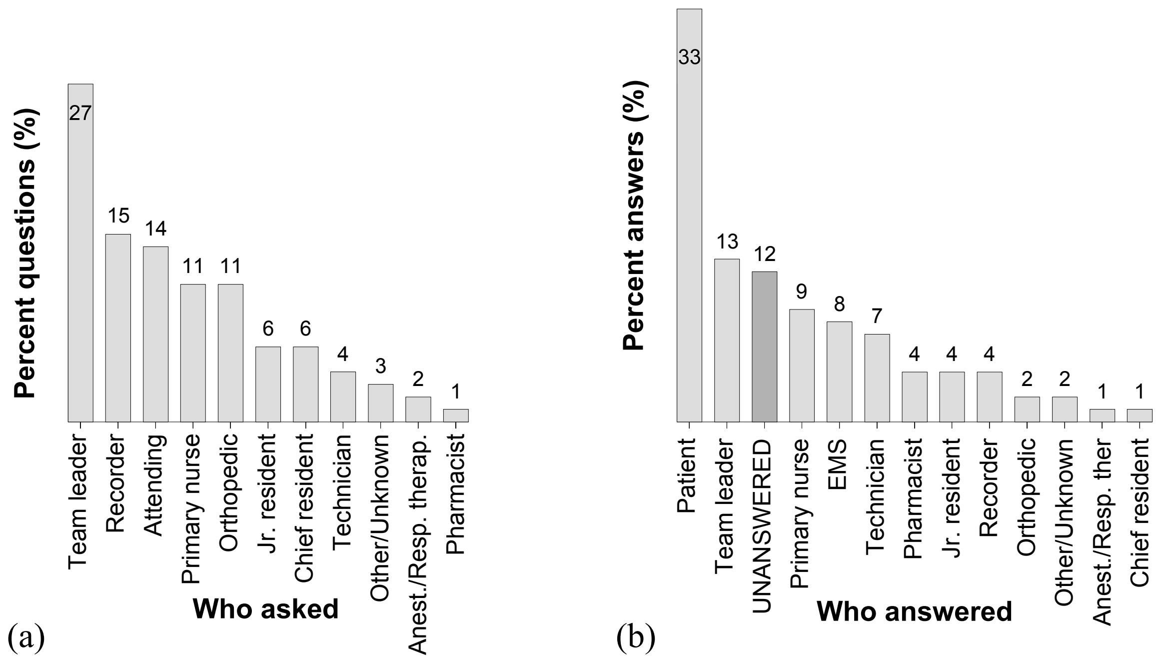


Figure 6-7: (a) Frequency of inquiries by role, in the first 10 resuscitation events. (b) Frequency of responses by role, in 10 resuscitation events.

In summary, questions asked during or immediately after information handover while the EMS crews were still present were mostly to clarify the story provided in the initial EMS report. On the other hand, questions asked among the trauma team members after the EMS crew left indicated gaps in the teams knowledge and information needs. These gaps occurred either because the EMS crew did not report needed information, or because team members missed the report, or forgot reported information by the time they needed it. These findings highlight the need for memory aids to help the trauma team recall the reported information.

6.5.1. Information providers and sources

An information provider is a member of the team who acquires information directly from the environment via observation tasks (physical examination, instrument reading, manual measurement, or sensing).

Not surprisingly, patients' answers appeared to be a key information source in six out of ten resuscitations (Figure 6-7(b)). The patients provided information about their medical history and feeling pain. For example, resuscitation # 10 had the highest number of questions in the evaluation category (50% of the total) because of inquiries by the orthopedic surgeon performing motor and sensory exams. This type of examination obtains feedback from the patient when assessing motor and sensory status. Resuscitations in which patients were not able to provide answers also led to an increase in the number of questions within the team (e.g., resuscitations # 2 and 4). In these examples, the team leader, attending physician and recorder nurse queried the paramedics and each other repeatedly about the patient's medical history, increasing the overall number of questions to obtain the data that otherwise might have been provided by the patient.

Information about the patient's evaluation, status, and treatments was provided by different members with the team leader being the primary source followed by the primary nurse, paramedics and technicians (Figure 6-7(b)). Among the 581 questions, 130 (22%) were not directed to a specific member, but rather to the whole team, suggesting that information can be expected from several sources.

6.5.2. Information seekers

An information seeker is a member of the team who inquires about patient information and team activities (inquiry or clarification).

The data analysis revealed that the team leader is the most frequent information seeker, followed by the recorder, attending physician, primary nurse and orthopedic surgeon (Figure 6-7(a)). Because of the team leader's leadership role, questions by this individual are focused on obtaining information needed to arrive at the correct diagnoses.

In contrast, the recorder nurse seeks information to document the event, while the attending physician seeks updates needed to supervise team activities.

Observations suggest that the team leader gathers information mostly through inquiries rather than through direct observations. For example, instead of turning around to read the patient’s vital signs from the monitor, the team leader asks the team about the vital signs. The reason for this behavior could be that the dynamics of the situation require that the team leader maintain focus by minimizing physical activity and communicating verbally to obtain needed information. As already mentioned, the recorder nurse is located on the opposite side of the room from the patient to avoid interference with those with patient contact. While this distance is not great, the noise and activity within the room make it necessary for the recorder to make frequent and repeated inquiries to obtain needed data. Not surprisingly, questions were frequent about vital signs and other patient parameters critical for monitoring the patient. This finding is consistent with the care providers’ need to continuously obtain and update information about patient status.

It is surprising that the team leader asked the attending physician very few questions (Figure 6-7(a)) given that the team leader’s role is subordinate to the attending physician’s role. In contrast, the attending physician asked the team leader many monitoring and coaching questions. The team leader never asked the supervisor what to do. As already mentioned, due to the urgency of the situation, collaborative problem solving happened rarely—the team leaders were working under the ATLS protocol and their activities were not free form.

Table 6-7: Main information categories, who memorized this information (providers), and who inquired about it (seekers).

Information category	Major providers	Major seekers
Mechanism of injury & pre-hospital information	EMS, Recorder	Team leader, Attending, Chief resident, Recorder
Patient demographic information	EMS, Patient, Recorder	Recorder
Patient medical history	Patient, Recorder	All leadership roles (ATP, CHF, TL), Recorder
Airway	Anesthesiologist, Respiratory therapist, Team leader	All leadership roles (ATP, CHF, TL), Recorder
Breathing	Team leader, Jr. resident	All leadership roles (ATP, CHF, TL), Recorder
Circulation/transfusion-fluids	Primary nurse, Team leader, Technician	All leadership roles (ATP, CHF, TL), Recorder
Disability	Team leader, Orthopedic, Jr. resident	All leadership roles (ATP, CHF, TL), Recorder
Physical examination findings	Team leader, Chief resident	All leadership roles (ATP, CHF, TL), Recorder
Vital signs	Technician, Recorder	All leadership roles (ATP, CHF, TL), Recorder
IV access	Primary nurse	All leadership roles (ATP, CHF, TL), Recorder
Treatments provided	Team leader	All leadership roles (ATP, CHF, TL), Recorder
Medications administered	Primary nurse, Pharmacist, Recorder	ATP, CHF, TL, Primary nurse, Recorder
Changes in patient status	Team leader	All leadership roles (ATP, CHF, TL)
Equipment	Technician	Primary nurse, Recorder
Team monitoring & teaching	Team leader, Jr. resident	Attending, Chief resident
Administrative issues	Recorder	Team leader, Primary nurse, Recorder

6.6. Use of Transactive Memory

An analysis of trauma teams' tasks and information flow showed that trauma team members rely heavily on specialization and delegation. Further evaluation of who reported or asked what type of information offered valuable insights into who are the custodians of specific information types (Table 6-7). Leadership roles (attending physician, chief resident, team leader) mostly relied on other roles (e.g., primary nurse, clinical care technician, nurse recorder) to acquire, validate, temporarily memorize and recall relevant information. Leaders delegated the task of memorizing instantaneous values of variables such as vital signs, their past values (history) and possible trends. In addition those in leadership roles delegated the tasks of remembering the timing to read-out new values, checking the validity of the recorded values, e.g., to detect values recorded by a loose sensor or a faulty instrument and instrument troubleshooting. Because these same services were available to all other team members, rather than only in a dyadic relationship "leader-subordinate," this assignment of tasks helped avoid repetition.

Inquiries (Q) and responses (RS) appeared to be the primary means of using transactive memory in trauma teams. As reported above, an analysis of the inquiries revealed 16 major categories with over 80 types of information needed in a typical resuscitation (Table 6-4). Some of the top information seekers (like team leaders and primary nurses) were also among the top information providers (Figure 6-7(a)). This finding implies that these seekers acted as secondary providers, i.e., they responded to inquiries based on the information they acquired earlier from primary observers. For example, the superiors (attending physician or chief resident) often asked the team leader about the accident details. This type of query occurred because EMS paramedics, primary providers of this information type, left the emergency department once they debriefed the team and delivered the patient. Thus, the team leader needed pre-hospital information not only to be able to conduct an evaluation of the patient, but also to be able to inform other team members who were either late or were busy with other tasks during patient handover. Consider the following example from resuscitation # 4:

> The chief resident walks in at about 6 minutes after the evaluation has started. He starts posing questions to the team about the patient history and mechanism of injury. He is also requesting updates on what has been done so far. Rather than obtaining this information from the recorder, he talks to other team members:
>
> Chief (enters)
> Chief (talks to TEAM) *Do we have blood pressure yet?*
> Team leader (talks to Chief) *Yes we do, 190 something*
> Recorder (talks to Chief) *191 over 78.*
> Chief (talks to TEAM) *What do we have for access?*
> Primary nurse (points to the patient's left arm, talks to Chief) *In the left, 16, forearm, and nothing on the right yet.*
> [two minutes later]
> Chief (talks to TEAM) *What was his mental state when he came in?*
> Primary nurse (talks to Chief) *He was combative.*

Chief (talks to Primary nurse) *Restrained or wearing a seatbelt?*
Primary nurse (talks to Chief) *Seatbelt.*

Results also revealed low awareness of mutual information needs that resulted in inefficient use of transactive memory. This factor can be measured by using the concept of "anticipation ratio" (Entin & Serfaty, 1999)—the ratio of the number of communications providing information (RP) to the number of communications requesting information (Q). An anticipation ratio >1.0 suggests that team members are anticipating the information needs of others and are "pushing" information towards them, while an anticipation ratio <1.0 suggests that little anticipation is occurring requiring team members to request ("pull") information from others (Entin & Serfaty, 1999). In the 10 resuscitations, an average anticipation ratio of 0.73±0.12 (range 0.63–0.94) was observed, suggesting that team members were poorly anticipating each other's information needs. It can be assumed that the resulting inquiries contributed to noise in the trauma bay and impaired communication because many questions were repeated. The data showed, on average, 8.4 clarifications, 13.6 acknowledgements, and 2.2 message relays per resuscitation. All these communication categories added to the general noise in the trauma bay and affected communication efficiency.

Although communication between team members is essential for transactive memory, the findings suggested two problems: 1) due to the collaborative nature of assessment, it is critical that information is transferred to all team members; the absence of an effective alternate method mandated that most information exchange was verbal requiring team members to speak frequently and in short intervals; 2) because of overlapping voices and ambient noise, some speech was poorly audible which required team members either to speak loudly or repeat their inquires, responses, and reports several times.

6.7. Modeling Decision Making in Trauma Resuscitation

To obtain insights into the decision-making processes in trauma resuscitation, an initial model of decision making in trauma resuscitation has been developed. The model focused on rule-based behaviors (RBBs) of Rasmussen's SRK framework because it was found that trauma teams mostly engage in RBBs (see discussion in Section 6.3.4). Because RBBs are dominant in trauma care and more likely to be distributed across team members than either skill- or knowledge-based behaviors, RBBs are most relevant for studying teamwork errors.

Trauma team members work towards satisfying resuscitation goals by executing expert rules of the type:

```
WHEN diagnosis DO treatment                                    (R-1)
```

where *diagnosis* is a true or false statement about the injury condition, and *treatment* is a one-entry, one-exit sequence of actions. For example, if the patient is diagnosed with a pelvic fracture that resulted in internal bleeding, a treatment may be to administer intravenous fluid or blood, or wrap the pelvis with a specially designed strap to stabilize the fracture and reduce bleeding. In this case, each treatment is a multiple step procedure.

To reach a diagnosis, a trauma team must first observe symptoms (or signs) of the injury. The expert rule can therefore be modified as:

```
IF injury THEN symptoms DO treatment                           (R-2)
```

where *symptoms* can be expressed as a logical formula, such as: *symptom1* AND *symptom2* OR *symptom3* NOT *symptom4*. The rule can be evaluated iteratively using partial evidence as it becomes progressively available.

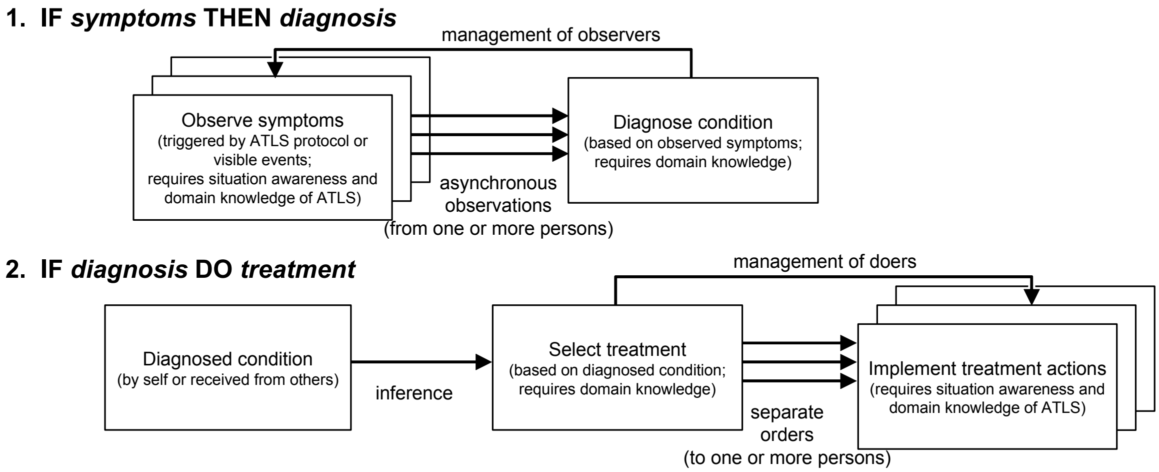


Figure 6-8: Workflow for expert rule (R-2b): IF *symptoms* THEN *diagnosis* DO *treatment*, split in two parts.

Rule (R-2) is written in the temporal order of how its components occur: an injury is followed by the symptoms, which in turn are followed by a treatment. Another way to express (R-2) is in the order a person would cognitively process this rule:

```
IF symptoms-observed THEN diagnose-condition
DO implement-treatment                                  (R-2b)
```

For simplicity, it can be assumed that each goal is satisfied by executing a single rule. Goals that are more complex can be satisfied with chain or hierarchical (nested) rules. The execution of a rule can be split into two stages (Figure 6-8). It is assumed that each connecting arrow represents communication. If the system executing the rule is an individual, the arrow represents intrapersonal communication (Hutchins, 1995). If the system is a team where different boxes can be performed by different team members, the arrow represents interpersonal communication.

As in the example resuscitation from the narrative, a rule can be written for management of a pelvic fracture:

```
IF (pelvic-rock-positive AND rectal-exam-blood
AND blood-pressure-drop AND...)
THEN pelvic-bleeding DO control-bleeding by pelvic-binder
OR fluid administration OR ...                         (R-3)
```

The ATLS protocol provides an ordering of the execution of expert rules, representing a resource for organizing the team's behavior. ATLS is not a linear process but instead has many branch points that can be taken based on the results of previously executed rules. Some rules can be executed in parallel if they are not mutually conflicting.

To successfully link symptoms with diagnoses (part 1 in Figure 6-8), the team needs to know and memorize the list of symptoms to observe (P1.1), the order of observations when important, and the outcomes of all observations (P1.2). A team with labor division needs to gather all or partial observations for one individual to interpret the diagnosis. To link diagnoses with treatments successfully (part 2 in Figure 6-8), the team needs to know and memorize the diagnosis (P2.1), the selected treatment (P2.2), the sequence of actions for the treatment (P2.3), and confirmation that each action has been completed (P2.4).

The key problem that was observed is that decision making in trauma resuscitation relies on human memory with virtually no external memory aids. The team leadership relies on other roles to acquire, retain, and validate information needed for decision making. As described in Section 6.3.1, the observations needed for diagnosis are completed at different times, sometimes with many minutes between individual observations. Using verbal communication solely, allows only for sequential acquisition of the required facts. Since decision makers in trauma teams rely primarily on verbal communication, they collect pieces of information one-by-one until having enough to make a diagnosis and decide on treatment. This paradigm imposes a high load on their working memory. As trauma teams primarily rely on collective memory, observations are recalled through questions and responses. This process can result in communication inefficiencies, such as loss of information (e.g., unanswered questions or unreported findings), repeated questions (e.g., questions about medical history are often asked by different team members at different times throughout the event), clarifications (e.g., requests for repeating information), and message relays.

6.8. Summary

This chapter presented a detailed analysis of trauma teamwork that used methods described in Chapter 4. The chapter started with an example narrative, which described one critical resuscitation. This example illustrated several aspects of trauma teamwork as well as the problems faced by trauma teams when treating severely injured patients. Each of the subsequent sections then focused on one aspect of trauma teamwork and provided detailed descriptions of problems by drawing on examples from other resuscitations that were observed over the course of the study. The chapter ended with a simple model of trauma teamwork, which described the decision-making process in trauma resuscitation.

The most commonly observed problems during trauma resuscitation were that of communication. Because trauma teams rely on verbal communication to share evaluation findings, delegate tasks, and make decisions, inefficient communication can have negative impact on the decision-making process. Communication inefficiencies included: unreported evaluation findings, failures to propagate information, partial reports and partial orders (resulting in repeated questions and clarifications) and difficulties in tracking the progress of multi-step procedures (resulting in an increased amount of communication exchanges among trauma team members).

The results also showed minimal use of external memory aids such as the trauma flowsheet, physicians' progress notes and the whiteboard outside the trauma bay. It was noted that trauma teams function as transactive memory systems where each member of the team, with a clearly assigned role, acquires and temporarily stores information in his or her working memory. This information is then retrieved during the decision-making process when the team leader inquires about collected information, integrates the data and makes the decision. Further analysis, however, revealed that the functioning of the team as a transactive memory system has its drawbacks because information is collected asynchronously so that by the time it is needed, it might be forgotten.

An analysis of the decision-making processes showed that trauma teams engage in relatively few group decision-making tasks. Decisions are mainly made solo, by the leadership roles, and rarely involve long deliberations.

The following chapter presents the final product of this thesis. It discusses the most commonly observed problems, proposes four hypotheses about the causes of teamwork errors, and presents a novel classification scheme of team errors, which was derived based on the results presented above.

Chapter 7

Teamwork Errors

7.1. Chapter Overview and Purpose

The previous chapter described the research findings, focusing on properties of trauma teamwork and teamwork inefficiencies. The purpose of this chapter is to briefly discuss those findings, present four hypotheses about teamwork errors, and propose a novel classification scheme of team errors.

7.2. Discussion of Observed Problems

Trauma teams have obvious challenges performing the multi-step evaluation and treatment procedures required for ATLS protocol. During trauma resuscitation, there is a lack of longitudinal tracking and integration of information. This problem occurs not only with time series data, such as periodic blood pressure measurements, but also with individual observations. Trauma teams make judgments based upon facts available immediately and rarely consider the facts found earlier in the process. This finding is well known from general research in decision-making under uncertainty (Hastie and Dawes, 2001). The information presented in this thesis offers an insight into why this happens in trauma resuscitation teamwork.

An important issue raised previously was why trauma teams miss so many cues during the primary survey. Although team members effectively observe the needed cues to make a correct diagnosis, they do not apply these findings to properly execute rules. In the example narrative, there were no overt signs of physicians using weak cues in the decision-making process. If they had used the weak cues, this would have visibly affected their subsequent decisions, but it had not. They might have used weak cues when the correct diagnosis was made and appropriate treatments were selected. However, by this time, x-rays showing the diagnosis (a strong cue) became available rendering any previously observed weak cues superfluous. It appears that given a weak cue, physicians defer their diagnosis until stronger evidence becomes available. If taken individually, the symptoms in the IF-part of (R-3) are often insufficient to derive a conclusive diagnosis. When integrated, these cues may offer a strong evidence for a diagnosis. However, to do this, these cues need to be combined with other cues, often obtained by other team members at different times. The findings of this study suggest that trauma teams have difficulty integrating weak cues for quickly arriving at a diagnosis, especially when these cues are obtained by different team members.

Based on a simple model of trauma teamwork presented in Section 6.7, it is proposed that the trauma team represents a team cognition system that is functioning sub-optimally. In theory, an optimal decision system would use all available evidence to arrive at a diagnosis. In practice, the trauma team unintentionally ignores weak evidential information and relies only on strong cues. Unlike the ideal case, the decision maker in practice has problems with integrating multiple weak-but-relevant cues because they become available at different times and have to be remembered and later recalled. A key contributor to this integration problem is that the observer of a cue does not report uncertain diagnoses to the team. They may hold these provisional diagnoses in their working memory, but they do not externalize them in a medium more permanent than human memory. Because of the amount of data that a trauma team must process, the memory of weak cues may no longer be available when needed. Interviews with trauma surgeons on the research team corroborated this speculation that trauma teams engage in a sub-optimal decision-making process.

7.3. Team Errors Hypotheses

Based on the analysis of critical situations in observed resuscitations that resulted in inefficiencies and near-miss errors, as well as on the model of trauma teamwork, four hypotheses about teamwork errors are proposed. The inefficiencies discussed above were observed in both routine and critical cases. In routine cases, these inefficiencies were less conspicuous because they had low potential impact on the patient. For patients in critical conditions, the potential of those inefficiencies to lead to adverse outcomes is more apparent.

H1: Asynchronous gathering of information by a team results in significantly poorer data integration than synchronous data gathering

To reach a diagnosis, a trauma team must first observe signs of an injury. Observations are primarily done by the team leader who makes major decisions and supervises patient care. However, as in most other team-dependent, high-reliability work settings, trauma teamwork is characterized by both cognitive and physical divisions of labor. This means that other team members, such as the orthopedic surgeon, junior residents, nurses, or technicians take an active role in information gathering. To reach a diagnosis successfully, the team must know and memorize the list of symptoms to observe, the order of observations (which is prescribed by the ATLS protocol) and the outcomes of all observations. As trauma teams represent teams with labor division, various team members need to gather all or partial observations for one individual to interpret the findings. As various trauma team members observe signs of an injury, they verbally convey information to the team leader who then mentally integrates the data and makes a decision. This, however, makes evidence gathering sporadic, time-consuming and cognitively demanding. The observations needed for a diagnosis are completed at different times, sometimes with many minutes between individual observations. As shown in the example narrative, the sporadic accumulation of evidential information delayed the diagnosis of internal bleeding due to the severe pelvic fracture. The team confirmed, localized and treated internal bleeding only after reviewing the x-rays that became available 20 minutes after the evaluation had started. This temporal accumulation of data was supported by observations from other resuscitations. It was noted that asynchronous data gathering makes it difficult for a single decision maker to collect evidential information and make timely and effective decisions. The team leader relies on other roles to acquire, retain, and validate information needed for decision making. Observations have to be memorized and recalled. As trauma teams primarily rely on collective memory, observations are recalled through questions and responses. This process leads to poor data integration, with most findings being considered in isolation.

H2: Failure to propagate critical information results in significantly poorer decision making than active sharing of critical information

The trauma bay is a noisy place. Information about patient status is conveyed and team activities are coordinated mostly by speech. Team members often raise their voices to be able to transfer information. Many kinds of equipment generate background noises. Sometimes, even the patient creates noise because of pain. Noise however is not the only cause of information loss. Information can also be lost if not reported. Team members often fail to propagate critical patient information. Several reasons may account for this failure. First, team members simply forget to either obtain or report information. A common example is the failure to report vital signs, an error observed in all resuscitations. The technician and primary nurse are assigned to call out the patient's vital signs periodically for everyone, but often forget to check the monitor. Even when the vital signs are called out, most often, not all parameters are reported. Second, given the large amount of information gathered during resuscitation, individuals who obtain pieces of information often ignore less important items, e.g., weak cues. A commonly observed error is failure to report positive or uncertain examination findings. In two resuscitations, the orthopedic and junior residents failed to report findings from their assessments that turned out to be critical later in the event. Because they found everything normal, they might have decided, consciously or unconsciously, that reporting these findings would contribute no new information and would only add to the ambient noise. However, propagating information makes it part of collective memory and facilitates a team's situational awareness. Failure to report critical patient information, even when positive, negatively affects decision making and can lead to adverse patient outcomes. Each team member may be doing their work correctly, but because of a failure to propagate information, they are failing at the team level.

H3: Concurrent task execution over shared resources significantly increases the possibility of adverse patient outcomes than linear task execution

The work done by the trauma team involves a great deal of parallelism. The primary nurse can start setting up the intravenous access immediately upon patient arrival (part of step C of the ATLS), without a specific direction from the team leader. At the same time, the team leader may start with the chest examination (part of step B), and the orthopedic surgeon may start his assessment for fractures (part of secondary survey). These variations in the order of tasks prescribed by the ATLS rarely contribute to adverse patient outcomes. Problems, however, occur when team members perform their tasks simultaneously over the same body part, i.e., a “shared resource.” As described previously, in one resuscitation, the orthopedic resident repeatedly lifted the patient’s arm while the team leader was working on chest tube insertion on the same side. This interference prompted the attending physician to step in and ask the orthopedic to defer his examination to a later time. In the resuscitation presented in the narrative, the primary nurse started drawing blood samples while the team leader wanted to take x-rays. He decided to hold until the primary nurse completed the blood draw. This decision resulted in delaying the x-ray results.

H4: Tracking the progress of multi-step procedures results in significantly more communication exchanges when multiple people are involved

These management errors occur when team members lose track of the progress of multi-step procedures such as the administration of medications or fluids. Figure 6-8 shows the management feedback loops where the supervisor (the team leader) ensures task completion by others. When a person is executing a multi-step procedure alone, it is relatively easy to keep track of the current step. When multiple people are involved, it is hard to track the progress, especially if the supervisor is also busy with another task. For example, in the example resuscitation from the narrative, the team had difficulty monitoring the administration of emergency medications. A similar example is the procedure for administering intravenous fluid that includes retrieving, setting up, starting

Table 7-1: Proposed classification of teamwork errors.

Error Type	Description
Individual error	Selection of an inappropriate rule or incorrect execution of an action
Concurrency error	Concurrent execution of conflicting rules leading to a collision over shared resource
Communication error	• Loss of information during communication • Failure to propagate information: - Failure to report an uncertain belief about a diagnosed condition - Failure to report an observation • Incorrect understanding of a communication • Providing circuitous answer to an inquiry
Interpretation error	Incorrect inference based on underspecified (lacking or partial) information
Management error	Loss of track of progress of a multistep procedure

up, and periodic monitoring. Difficulty with tracking fluid administration was observed in most resuscitations including the example event from the narrative. An individual error of losing track of one's own activities differs from a management error because the latter relates to the failure to monitor what others are doing. In this case, some team members may know the current step, but the supervisor does not know it. Other management errors include failure to delegate actions appropriately, failure to monitor team member behavior and reports and failure to mediate in resolving conflicting actions by different team members.

7.4. Classification of Team Errors

Individual errors happen when a person either works alone or in a team, but isolated from others. Unlike that, team errors happen when there are minimum two people collaborating. Individual errors in trauma resuscitation occur when a team member selects an inappropriate rule to work on, or incorrectly executes any needed action (any single box in Figure 6-8). The purpose of ATLS protocol is to guide the rule selection process. Selection of a wrong or suboptimal rule by someone in a leadership role is more likely to have adverse effects. Individual errors may be due to inexperience, overload, or distraction (Reason, 1990). Individual errors may be exacerbated by teamwork, but they are not unique to teamwork.

Based on the four hypotheses about teamwork errors presented above, four types of team errors are proposed (Table 7-1). Errors are defined as actions that result in wrong or suboptimal outcomes of rule execution.

1. *Interpretation errors* occur when team members incorrectly interpret evidential information. Although also found in individual work, interpretation errors appear in teamwork for different reasons. Trauma team members observe different things and report their findings to the team leader, i.e., the person who integrates data and makes decisions. However, sometimes the observer of a cue does not report findings to the team. This process leads to poor data integration, hence an interpretation error, because the team leader acquires information asynchronously or misses some completely. Another interpretation error may result from acting on insufficient evidence due to a failure to collect additional observations needed for reliable application of the rule.
2. *Communication errors* occur due to noise, interference, and misunderstanding. Any of the communications between the boxes in Figure 6-8 are subject to errors. The recipient may be registering the communication but incorrectly interpreting it or choosing not to react. Failures to report critical information are also classified as communication error because they represent a failure to propagate information between team members, which results in team's incomplete situational awareness and increases the amount of communication exchanges among team members. Similarly, failure to report uncertain beliefs about a diagnosed condition is classified as a communication error. When reporting uncertain beliefs, team members alert others in the team to look for opportunity during evaluation to

combine weak cues into a reliable diagnosis. Although communication errors rarely cause direct harm to the patient, cumulatively they can lead to interpretation or management errors. These may unnecessarily delay diagnosis and have serious consequences.

3. *Concurrency errors* occur because of concurrent execution of conflicting rules, which leads to collisions over shared resources.
4. *Management errors* occur when team members lose track of the progress of multi-step procedures such as administration of medications or fluids. When several people are involved, it is hard to track the progress, especially if the team leader is also busy with another task. Other management errors include failure to delegate actions appropriately, failure to monitor team member behavior and reports, and failure to mediate in resolving conflicting actions by different team members.

One may argue that trauma resuscitation teamwork, despite its complexity, is an easier problem to represent compared to an unconstrained team activity. The roles are relatively constrained, the physical artifacts are reasonably distinct, there is a clear locus of activity (the patient), and the entire process is governed by a well-defined protocol. It may then appear that these characteristics of trauma teamwork limit applicability of the teamwork model and the above-presented error scheme to other domains. However, most safety-critical teams are highly structured, and their work is governed by specialized rule-based protocols. It could therefore be stated that the results of this study generalize to other dynamic, safety- and time-critical work settings.

7.5. Summary

This chapter discussed the most commonly observed problems in trauma resuscitation using the simple model of trauma teamwork presented in the previous chapter. Based on the findings of this research coupled with the model of trauma teamwork, four hypotheses about teamwork errors were then presented. The chapter concluded with a novel classification scheme of team errors. The following chapter discusses challenges for system design to support the work of trauma teams, and by extension, the work of teams in other time- and safety-critical operations.

Chapter 8

Challenges for Technology Design

8.1. Chapter Overview and Purpose

The study showed that information acquisition, sharing and archiving as well as decision making in trauma resuscitation are only minimally supported by technology. The presented findings highlight several opportunities for improving the efficiency of trauma teamwork.

8.2. Technology Opportunities

Based on the findings presented in this research, several opportunities for developing technology to address the problems of trauma teamwork have been identified. As previously described, trauma teams rely minimally on collaborative decision- making, with most decision-making concentrated in the command physician role. A group-decision support system (GDSS) does not, therefore, appear to be the most appropriate solution. A key role of technology should be to optimally display information for the team and facilitate information flow from providers to seekers, thus obviating the need for verbal communication in certain instances and preventing communication breakdowns. It is known from other domains that information externalization to cognitive artifacts helps reduce the cognitive effort required of the team (Hollan, Hutchins & Kirsh, 2000). However, unlike other domains, a surprisingly low amount of externalization of information was found in trauma resuscitation. It can be speculated that the reason for this finding is that externalization requires time and effort, which are two very limited resources during trauma resuscitation. As a compromise, trauma teams appear to rely on a verbal implementation of transactive memory. The current practice of relying heavily on other members to gather, store, and recall information may imply that the trauma teams may be disinclined to use new technological aids that require their direct interaction.

Based on focus groups with physicians and nurses, it was found that team members had several common views on the implementation of technology in a trauma resuscitation setting:

- New technologies must be intuitive to use and must not interfere with the sequence of care.
- Individuals have variable willingness to accept new technologies in a time critical environment. This factor may be the greatest initial impediment to implementation and must be considered in the design of new technologies in this setting.
- Team members are skeptical of computerized decision support but are receptive to alternative methods of information transmission and display.
- Communication with consultants and other trauma team members outside of the trauma bay is time-consuming and inefficient.
- Information (vitals, reminders, etc.) provided by decision support systems should be available only when needed.

  "*If we have a digital voice that's reading me the blood pressure every five minutes, I would just shut that thing up… it should be easily accessible only when I want it!*" (resident4)

- Technology should provide information about medications and treatments when administered not when ordered.

  "*If someone takes morphine out of the cabinet and says 'I am pulling that morphine from the cabinet,' nobody cares… we don't know yet if that went into* *the patient… so I think if you really want to get most accurate way of finding out what this patient got, it should be when that needle is inserted into the IV tube, not when it's coming out of the cabinet or when it's thrown away because no one will know what happened in between.*" (resident1)

- Supporting technologies are needed for improving communication with individuals remote from the emergency department.

  "*Communication technologies, like close-talking microphones and Bluetooth headsets, will be useful for verbal orders… for example, if I could say 'order CAT scan, head and neck' and that immediately goes into the computer… so I don't have to have my interns running around trying to find a computer to put that order in, when I need them in the room to help out resuscitate the patient… In the trauma bay, it's going to be too chaotic, it's going to be very loud, you'll be trying to focus on 'what did this thing just say to my ear' and then trying to answer back… I think it won't work… it will be useful for putting orders in… I don't think it will be useful for individual communication among people in the trauma bay.*" (resident3)

8.2.1. Information displays for distributed cognition

As reported previously, communication inefficiencies appeared to be the most commonly observed problems during trauma resuscitations. Despite its limitations, speech is a critical component of information sharing in trauma resuscitation and is the basis for transactive memory functioning. Findings reported in this thesis suggest that verbal communication strains a team's cognitive capabilities but is accepted as a solution because of the lack of an effective alternative.

Using verbal communication, solely, allows only for sequential acquisition of the required facts. Since decision makers in trauma teams rely primarily on verbal communication, they collect pieces of information one-by-one until having enough to make a diagnosis and decide on treatment. This paradigm imposes a high load on their working memory. Also, increased communication volume during critical situations negatively impacts information sharing and decision making. The apparent inefficiencies from repeated questions and reporting can be reduced by introducing better information displays. If different pieces of information were simultaneously visualized, there is a possibility of converting effortful computational tasks into relatively effortless perceptual recognition tasks. Selected information could be continuously displayed on a wall display. Other information could be displayed only when requested. For example, supporting team members could interactively retrieve and display needed information. Given the simultaneous visibility of all required pieces of information shown on a kind of "information dashboard," a decision maker could arrive at diagnoses and treatments more rapidly and accurately.

Similarly, simultaneously captured and displayed information would also benefit the nurse recorder who faces various difficulties in keeping the trauma flowsheet current and complete. Information displays could facilitate the documentation process because information would be more readily available. For example, if vital signs information is captured and displayed continuously, the nurse recorder will not depend on verbal reporting by other team members.

8.2.2. Interaction design for trauma teams

Trauma teams already use technological aids in measurement and observation tasks. Unfortunately, these are not networked and their data are not digitally recorded and transferred to an electronic trauma flowsheet. New information technologies could help in data recording and integration.

It is unlikely that all team members will equally interact with any new information system. Some members may be able to enter data and navigate computer screens and menus to retrieve information. Other team members will be too busy for this interaction and will most likely continue relying on others for information, i.e., they will continue relying on verbal access to the team's collective memory. The findings of this study indicated that the team leader is the busiest team member throughout the resuscitation. Thus, it can be expected that the leader will at most look at information on wall displays but not actively interact with the computer system. On the other hand, the nurse recorder and attending physician are able to look away from the patient and might be more receptive to interactive technology.

Providing the nurse recorder with an interactive, electronic trauma flowsheet may not solve the problem of information acquisition and documentation. The findings of this study showed a number of challenges to keeping the trauma flowsheet current and complete. A straightforward solution would be to substitute the paper-based trauma flowsheet with digital forms that rely on manual data entry. However, an electronic trauma flowsheet may not adequately support the recorder's tasks and the overall goals of the trauma resuscitation, as previous work described below has shown.

Electronic health records are increasingly seen as a solution to the highly fragmented and inefficient paper system currently used in most medical settings. Attempts to computerize the process in trauma resuscitation began two decades ago (Gertner et al., 1994) and have not yet yielded a feasible solution. This failure to computerize the resuscitation process may not be surprising. Numerous studies have shown that computerized health records do not always result in improved accuracy or efficiency. Computerized order-entry systems may reduce some types of errors but increase the risks of others (Koppel et al., 2005). Zhou et al. (2009) found that the computerization of the nursing data in inpatient care affected nurse workflow because the system did not support entering informal patient information into the medical record. Studies within CSCW have found that computer systems often mischaracterize the use of paper-based medical records (Heath and Luff, 1996) and ignore the “invisible work” embedded in the activities of nurses and other medical staff (Star and Strauss, 1999).

The current paper-based system provides limited but important support for the complexity of recorder’s tasks. The multiple-page trauma flowsheet is spread over the recorder’s table and allows for simple navigation and quick data recording. The record is a living document that is being used by the recorder to help manage the resuscitation. The overall meaning and use of the document has evolved to aid the tasks and goals of the resuscitation team. For example, the document shows missing information prompting the recorder to request information. It is important that these same goals are retained when designing approaches that support the recorder’s documentation process.

Compared to current methods for electronic data entry, paper is easy to navigate and annotate, and simple to use (Sellen & Harper, 2001). If the paper-based approach cannot meet the demands of the task such as capturing simultaneous activities and reports, manual input to electronic forms is even less likely to do so. Rather than improving the efficiency of the documentation process, conversion to an electronic trauma flowsheet may make it more difficult for the recorder to input and access information efficiently.

A feasible alternative may be to partially automate the recorder’s tasks. Previous studies have suggested the potential benefit of automatically recording selected aspects of the patient encounter in trauma resuscitation. During simulated trauma resuscitations, computerized barcode data entry was used to record specific resuscitation events and was associated with fewer errors than data entry by handwriting (Chua et al., 1993).

Automatic capturing of communication exchanges might not be feasible in such a dynamic and noisy environment. However, automatic capture of data that originates from electronic devices, such as vital signs monitor should be relatively easy. Also, automatic tracking of medications, instruments and other artifacts used in the resuscitation process should be possible using radio-frequency-identification (RFID) tags and other technologies for localization and tracking. Partial automation of data capture has a potential to free the recorder from recording some aspects of the patient encounter and thus, allow more time for multitasking and recording simultaneous reports and activities.

Another team member that would benefit from automatic capture and display of data during trauma resuscitation is the team leader. Of all team members, the team leader needs the greatest amount of information to decide on appropriate actions and direct the team's activities. The challenge is to design an effective mechanism that allows the leader to retrieve and manipulate information efficiently while minimizing the amount of attention and cognitive effort needed for performing these tasks. One option is to have a team leader issue requests for information to other, less busy, team members who would interact with the system. It is unknown, however, how efficient and effective this type of indirect computer interaction will be. Another option is to equip the team leader (and other team members) with an earpiece and a close-talking microphone, allowing them to command the system via voice. The challenge of this potential solution will be designing a speech recognition module to function in this noisy environment. At times, the use of a stethoscope may conflict with wearing a headset, requiring the design of additional new technologies.

8.3. Summary

A key lesson from this study for system design is that there are no simple solutions. Better interface design can help in settings where workers primarily interact with technology, such as airplane cockpits or a nuclear power plant control room. In these settings, technology mediates interaction with the work domain. However, in trauma resuscitation, the workers primarily interact with the patient and various instruments. Rather than mediating interaction with the work domain, the technology would be considered a detour, which can hardly be practical in such a time-critical setting. To support trauma teamwork effectively, a system should continuously provide information necessary to prevent human errors. Physiological data from the patient could be automatically captured, and medications and other artifacts could be tracked using localization sensors to avoid errors inherent in manual clerical data entry. Once externalized in electronic form, this information could be processed (data validated and trends detected) and stored. The externalized information could be visualized in graphical form on an "information dashboard." Interaction with this system should be assigned to the less busy team members, such as the nurse recorder or attending physician.

Chapter 9

Conclusion

9.1. Chapter Overview and Purpose

The purpose of this chapter is to present the conclusions drawn from the findings of this research, to explain the study limitations and to propose areas for future work.

9.2. Conclusions Drawn from the Research Findings

This thesis presents findings from an ethnographic study that was conducted in a US Level 1 regional trauma center. The goal of the study was to investigate teamwork errors and present a classification scheme of team errors through a thorough examination of trauma teams' work, information acquisition and sharing and decision making. This study is a first step towards a long-term research goal: to design and develop an integrated information capture and display system to improve the efficiency of trauma teamwork.

To create a structured representation of teamwork and model collaborative activities in the trauma bay, the author of this thesis developed a research framework using both top-down and bottom-up approaches and applying several research and theoretical frameworks. Cognitive work analysis and the "skills-rules-knowledge" framework were used for studying the trauma resuscitation domain and developing an overarching framework for a behavioral, control-task coding scheme. The grounded theory approach was employed to develop subcategories in the coding scheme and derive hypotheses about the causes of teamwork errors. The overall research framework allowed the author to quantify the interactions and information flow in trauma resuscitations.

The thesis presented rich descriptions of trauma teamwork focusing on work properties such as information gathering, communication, information needs and sources and decision making. These rich descriptions included examples of inefficiencies in trauma teamwork that were observed throughout the study. Problems were identified in the ways in which trauma teams gather information used for decision making. Failures in team communication due to the use of verbal-only communication and a hierarchical team structure were also observed and described. It was concluded that trauma teams engage in sub-optimal decision-making processes. The decision maker, in practice, has problems with integrating multiple weak-but-relevant cues because they become available at different times and have to be temporarily memorized and recalled. A key contributor to this integration problem is that the observer of a cue does not report uncertain diagnoses to the team. They may memorize these provisional diagnoses, but they do not externalize them in a medium more permanent than human memory. Because of the amount of data that a trauma team must process, the memory of weak cues may no longer be available when needed. Based on these findings, a novel classification scheme of team errors was proposed. The four, team error types include: *interpretation* errors, *communication* errors, *concurrency* errors, and *management* errors. Challenges to designing technology to facilitate teamwork and prevent errors in trauma resuscitation were presented at the end of this thesis. A key role of technology should be to optimally display information for the team and facilitate information flow from providers to seekers. A major goal should be designing visual displays that contribute to the team's situational awareness. Interactive user interfaces for information presentation and retrieval, although appealing, may not be appropriate for this domain because the trauma team's main locus of attention is and should continue to be the patient.

9.3. Study Limitations

Several limitations of this study were identified.

First, video recordings of live trauma resuscitation were available for only 96 hours following the videotaped session. Because of this limitation, coding and analysis transcripts were done after the videos had been erased, creating interpretation issues.

Second, important conversations among trauma team members were held outside the trauma bay when teams left the room to take the x-rays. The recording setup could not capture these discussions. This limitation required sole reliance on field notes and observations made by the author during these episodes.

Third, conducting informal interviews with trauma team members was impossible after the events, when their memories of what happened were still vivid. Instead, critical episodes were discussed with trauma surgeons on the research team during video reviews.

Fourth, only 18 resuscitations were used for detailed analysis of trauma teamwork. Although 60 different treatments of trauma patients were observed, the time limit of 96 hours for video analysis also limited the number of resuscitations that could be videotaped and analyzed in a given timeframe.

Fifth, the study used one site only. It could be questioned whether what is reported in this thesis generalizes to other trauma centers. However, because most US trauma centers use the same staffing and procedures, the author of this work believes that the results are at least generalizable to sites within the US. Additionally, it may be difficult to generalize from trauma resuscitation to generic medical care, and from medical care to other disciplines. Even so, trauma resuscitation alone is an important domain.

9.4. Areas of Future Work

As discussed at the beginning of this thesis, this study is only the first step towards reaching a long-term research goal: designing and developing an integrated information capture and display system to improve the efficiency of trauma teamwork. To accomplish this goal, several areas of future work are proposed:

1. Further investigation of trauma teams' information needs. To provide detailed requirements for system design, it needs to be determined what input information is needed for rule-based behaviors, when it becomes available and how it is to be managed (exchanged, stored, and recalled).
2. Further investigation of decision making processes. The current model of trauma teamwork focuses on the rule-based behaviors of Rasmussen's SRK framework. In future work several options for refining this model will be considered such as adding skills- and knowledge-based behaviors, or applying other frameworks for modeling teamwork (e.g., Klein's RPD model). Unlike the SRK framework, which only provides a framework for organizing the observed behaviors, RPD (Klein et al., 1993) models cognitive functioning and is more sophisticated. Refining the current model with elements from the RPD model will yield a more accurate representation of teamwork in stressful scenarios.

3. Modeling and analysis of teamwork errors. This includes investigating how error types and their statistics link with different values of the parameters of the teamwork model.
4. Testing teamwork errors hypotheses. This area of work could be of potential interest to medical personnel in trauma centers. Testing the four hypotheses that this thesis proposed could yield important insights and suggest changes in evaluation protocol, team structure and work organization.
5. Extending this research to other functional domains and applying the research framework to assess if it generalizes across different domains. This area of future work could lead to a better understanding of teamwork in time- and safety-critical work settings.

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Appendix A

Informed Consent Form

CONSENT TO TAKE PART IN A RESEARCH STUDY

TITLE OF STUDY: A Mobile Collaborative System for Decision Aid in Pediatric Trauma Resuscitation

This consent form is part of an informed consent process for a research study and it will give information that will help you to decide whether you wish to volunteer for this research study. It will help you to understand what the study is about and what will happen in the course of the study. If you have questions at any time during the research study, you should feel free to ask them and should expect to be given answers that you completely understand.

After all of your questions have been answered, if you still wish to take part in the study, you will be asked to sign this informed consent form. The study doctor (the principal investigator) or another member of the study team (an investigator) will also be asked to sign this informed consent. You will be given a copy of the signed consent form to keep. You understand that you are not giving up any of your legal rights by volunteering for this research study or by signing this consent form. The study doctor is interested in finding out if you can fully understand the information you are being given. You need to fully understand the information before you can give your informed consent to enter into this research study.

Why is this study being done?

The purpose of this study is to evaluate information exchange between caregivers during trauma resuscitation.

Why have you been asked to take part in this study?

You have been asked to participate in this study because you participate in trauma resuscitations at Robert Wood Johnson University Hospital.

Who make take part in this study?

All practitioners who participate in trauma resuscitation will be asked to participate in this study.

How long will the study last and how many subjects will take part in it?

This study will last 5 years. We plan to videotape 30 trauma resuscitations during this time period. Based on estimates of the number of team members participating in trauma resuscitations, we estimate that up to 100 subjects will take part in this study.

What will you be asked to do if you take part in this research study?

Trauma resuscitations in the RWJUH Emergency Department will be videotaped. Your consent is being requested because you may be videotaped as part of your daily work in this area. The videotapes will be reviewed by experts in communication and information exchange to determine current practices in this setting.

What are the risks you might experience if you take part in this study?

Information contained in these tapes will not be used for disciplinary action or other work-related purposes. Videotapes will be reviewed and destroyed within 96 hours of taping. Videotaping will be used for research purposes only.

Are there any benefits for you if you choose to take part in this research study?

You will receive no direct benefit from taking part in this study.

What are your alternatives if you don't want to take part in this study?

Your only choice is not to take part in this study.

How will you know if new information is learned that may affect whether you are willing to stay in this research study?

During the course of the study, you will be updated about any new information that may affect whether you are willing to go on taking part in the study.

Who will be allowed to look at your research records from this study?

Your personal identity, that is your name, address, and other identifiers, will be kept confidential. Your role in the resuscitation (physician, nurse, respiratory therapist, etc.) will be designated using a code and your actual name will not be used. No record of the date of the resuscitation or your personal identity will be recorded to ensure your confidentiality. Your data may be used in scientific publications.

If you do not sign this approval form, you will not be able to take part in this research study.

You can change your mind and revoke this approval at any time. If you change your mind, you must revoke your approval in a written request to Dr. Tinti. Beginning on the date you revoke your approval, no resuscitation in which you participate will be recorded. Because methods to ensure confidentiality will not permit us to identify previous resuscitations that you have participated in or your role in these resuscitations, researchers may continue to use information obtained before you withdrew your approval.

In addition to key members of the research team, the following people will be allowed to inspect research records related to this study:

- The Institutional Review Board (a committee that reviews research studies)
- Officials of the University of Medicine and Dentistry of New Jersey
- Department of Health and Human Services-government agency that oversees and funds research involving human beings.
- Office for Human Research Protections (OHRP) (regulatory agency that oversees human subject research.)

Will there be any cost to you to take part in this study?

There will be no cost to you for participating in this study.

Will you be paid to take part in this study?

You will not be paid for participating in this study.

What will happen if you do not wish to take part in the study or if you later decide not to stay in the study?

You understand that you may choose not to be in the study. If you do choose to take part it is voluntary. You may refuse to take part or may change your mind at any time.

If you do not want to enter the study or decide to pull out of the study, your relationship with the study staff will not change, and you may do so without penalty and without loss of benefits to which you are otherwise entitled.

You may also withdraw your consent for the use of your data, but you understand that you must do this in writing to Dr Tinti. Videotapes in which you are recorded will be destroyed if you choose not to participate.

Who can you call if you have any questions?

If you have any questions about taking part in this study, you can call the study doctor:

Meredith Tinti, M.D.
Department of Surgery
732-235-7920

If you have any questions about your rights as a research subject, you can call:

IRB Director or IRB Chair at UMDNJ
Tel: 732-235-9807

Or you may contact:

IRB Administrator at Rutgers University at:
Rutgers University, the State University of New Jersey,
Institutional Review Board for the Protection of Human Subjects,
Office of Research and Sponsored Programs,
3 Rutgers Plaza, New Brunswick, NJ 08901-8559
Tel: 732-932-0150 ext. 2104
Email: humansubjects@orsp.rutgers.edu

What are your rights if you decide to take part in this research study?

You understand that you have the right to ask questions about any part of the study at any time. You understand that you should not sign this form unless you have had a chance to ask questions and have been given answers to all of your questions.

You have read this entire form, or it has been read to you, and you believe that you understand what has been discussed. All of your questions about this form and this study have been answered.

You agree to take part in this research study.

Subject Name:____

Subject Signature:____________________________________ Date:____________

Signature of Investigator or Responsible Individual:

To the best of your ability, you have explained and discussed the full contents of the study, including all of the information contained in this consent form. All questions of the research subjects and those of his/her parent(s) or legal guardian have been accurately answered.

Investigator/Person Obtaining Consent:_____________________________________

Signature:____ Date:____________

Appendix B

Interviewing and Focus Group Protocols

Interview Protocol and Questions for Assessing the Goals, Tasks, and Information Needs in Trauma Resuscitation

Ask the following questions for each step of the resuscitation protocol, starting with preparation (i.e., before patient arrives), primary survey (i.e., ABCD steps), secondary survey, and post-trauma resuscitation period:

1. What are the goals for this step?
2. How are these goals currently achieved?
3. What are the constraints in this step?
4. How are you currently solving them, if possible to overcome them at all?
5. List all sub-steps you do in this part of the protocol?
6. What information you need in this step (including sub-steps)?
7. What are current resources for that information?
8. What kind of tools/instruments/objects you use in this step?
9. What might be potential problems with them and how you go about solving these problems?

FOCUS GROUP GUIDE

Date: March 22, 2006
Group: Trauma unit chief residents at the RWJUH

SCRIPT & QUESTIONS

Hello, Good morning…
Thank you for coming.

I'm Aleksandra, and I'm graduate student at the School of Communication, Information, and Library Studies at Rutgers; this is Jacek, professor, also from SCILS; and this is Ivan, professor from Center for Advanced Information Processing Center at Rutgers.

The goal of our project is to lower the potential for medical errors during trauma resuscitations by introducing new technology that, we hope, will support the work of trauma team members.

To assess the feasibility of the proposed technology, we are talking with different groups of trauma team members, asking them about their opinions and feelings regarding the ideas we have.

We will start with a brief overview of our ideas and types of tools we plan to propose for use in trauma bay, and also about how a discussion group like this works. We hope these discussions will help us understand what can be improved in your work and most importantly, how it can be improved.

[If they haven't started eating donuts: You've probably noticed the donuts over there; please help yourself whenever you like]

Before we start talking about the project, I'd like to go over few ground rules for focus groups. The discussion will be confidential, meaning that our records will include information about your opinions, but it won't be possible to identify you from the records.

We would like to audio-tape this discussion. When we transcribe the interview and prepare a report, we will edit the information to remove specifics that would identify you. In other words, we'll be using your comments, but not your names.
Do we have your permission to tape our discussion?

There are other few things we should mention to you:

- Participation is voluntary.
- There are no obvious physical risks.
- There is no immediate direct benefit to you from participating; however, your participation will help us understand the way you do your work and how it can be improved.

Let us also take a minute for introductions and go around the table. Would you please introduce yourself briefly… tell us your name and something about yourself…
I'm going to turn the tape recorder on [TURN TAPE RECORDER ON].
Let's start with you… [GESTURE TO MY RIGHT]

Now about the ideas… I'll let Ivan give you an overview of the ideas we are proposing. We prepared these handouts for you.

- Hand out slides

[Ivan talks for about 10 minutes]

Now that you've heard the ideas I would like to ask you some questions.

1) To get started on a positive note, in what ways you think this technology could help <u>you</u> in performing <u>your</u> tasks during trauma resuscitations? Write down a note, like an example or two, so you remember your answer for our conversation. Feel free to refer to specific ideas we are proposing.

[WAIT FOR PARTICIPANTS TO STOP WIRITNG]

[GESTURE TO MY LEFT; HAVE EACH PARTICIPANT ANSWER]
Let's start from you this time…

[COLLECT THE PAPERS]

2) In what ways you think this technology could be obstructing <u>your</u> work or create problems? Again, write down a note so you remember your answer for our conversation, and feel free to refer to specific ideas that we are proposing.

[WAIT FOR PARTICIPANTS TO STOP WIRITNG]

[GESTURE TO THE PERSON IN THE MIDDLE; HAVE EACH PARTICIPANT ANSWER]
This time, let's start from you …

[COLLECT THE PAPERS]

3) Based on your experiences so far, how much you think adding new technology could be helpful in improving your work?

[GESTURE TO MY RIGHT; HAVE EACH PARTICIPANT ANSWER]
Let's start from you again…

4) How much time you think you would need to invest in learning to use this technology? Do you think you would have that time?

[GESTURE TO MY LEFT; HAVE EACH PARTICIPANT ANSWER]
Let's start from you this time…

5) I would like you to think about what else can be added to this list of ideas, or if you think that some of these should be removed from the list? Please jot words on the note pad, and we'll discuss your ideas.

[WAIT FOR PARTICIPANTS TO STOP WIRITNG]

[GESTURE TO THE PERSON IN THE MIDDLE; HAVE EACH PARTICIPANT ANSWER]
This time, let's start from you …

[COLLECT THE PAPERS]

6) Before we end this conversation, I would like to ask you if there is something that I should have asked you, but I didn't, or, perhaps if you have any questions for us.

Ivan, Jacek, is there anything else that you would like to clarify or ask?

OK. That's it for today. Thank you so much for participating. Your contributions will be very useful to us in our work.

FOCUS GROUP GUIDE

Date: May 2, 2006
Group: Trauma unit nurses at the RWJUH

SCRIPT & QUESTIONS

Hello, Good morning…
Thank you for coming.

I'm Aleksandra, and I'm a graduate student at Rutgers University.
With me here today are Marilyn, Jacek, and Ivan, who are all part of the project we are working on with Dr. Burd.

We are trying to find out how trauma resuscitations work because this is not our area. Our hope is to develop tools to support your work during resuscitations. That is why we would like to hear from you about your work, what works and what does not work and what kind of information you felt was missing or hard to get during a resuscitation.

We hope these discussions will help us understand where changes may be needed and what kind of tools we might try.

[DONUTS: If they haven't started eating donuts: You've probably noticed the donuts over there; please help yourself whenever you like]

Before we start, I'd like to go over few ground rules for focus groups. The discussion will be confidential, meaning that our records will include information about your opinions, but it won't be possible to identify you from the records.

We would like to audio-tape this discussion. When we transcribe the interview and prepare a report, we will edit the information to remove specifics that would identify you. In other words, we'll be using your comments, but not your names.
Do we have your permission to tape our discussion?

There are other few things we should mention to you:

- Participation is voluntary.
- There are no obvious physical risks.
- There is no immediate direct benefit to you from participating; however, your participation will help us understand the way you do your work and how new technology might help you.

Let us also take a minute for introductions and go around the table. Would you please introduce yourself briefly… tell us your name and something about yourself, what is your role, how long have you been working in hospital, etc. [Give an example from yourself].

I'm going to turn the tape recorder on [TURN TAPE RECORDER ON].

Let's start with you… [GESTURE TO MY RIGHT]
…

Thank you very much for introducing yourself.
Let us now start our discussion.

1) We thought that the best way to develop discussion is to have some kind of walk-through of trauma resuscitation, time wise. So, from the moment you hear a call for "Code40," tell us how you get organized. Would each one of you, please, answer briefly the following questions:

[GESTURE TO MY LEFT; HAVE EACH PARTICIPANT ANSWER EACH QUESTION]

Let's start from you this time…

(a) What is the first thing you think about when you hear the code?

(b) What are the things that each of you does to prepare?

(c) How do you decide who does what, that is what roles each person will take?

(d) Can you describe your duties, requirements for the role you take?

(e) How is the scribe nurse appointed?

(f) What do you need to know before the patient arrives?

2) Once the patient is in the room, how do you interact with each other?

(a) Do you always hear what is being said?

(b) What do you do if you don't hear something that was said?

(c) How do you learn about the current patient diagnosis, e.g., "airway is clear."

(d) How do you learn about what treatment is being requested?

(e) Does the resuscitation always follow recommended ATLS procedure? Can you describe?

(f) What do you do if you are not following ATLS procedure?

(g) How do you get information about vital signs?

(h) How is this information conveyed to others in the room?

[GESTURE TO THE PERSON IN THE MIDDLE; HAVE EACH PARTICIPANT ANSWER]

This time, let's start from you …

3) When was the last time you did resuscitation?

(a) How did it go?

(b) What was different about it? Why was it different?

[GESTURE TO MY RIGHT; HAVE EACH PARTICIPANT ANSWER]

Let's start from you again…

4) What are the most common problems you encounter during resuscitations?

(a) What would you do differently if you could change something?

[GESTURE TO MY LEFT; HAVE EACH PARTICIPANT ANSWER]

Let's start from you this time…

5) Who does the job of scribe nurse here?

(a) Can you hear all the information?

(b) Can you see all what is going on?

(c) Do you think people are responding to your questions?

(d) When do you decide to ask for information?

(e) Do you have enough time to enter all the information in the trauma sheet?

(f) Are there any problems with the current way of doing the job of scribe nurse?

(g) What would you change, if you could?

6) Before we end this discussion, I would like to ask you if there is something that I should have asked you, but I didn't, or, perhaps if you have any questions for us.

Marilyn, Ivan, Jacek, is there anything else that you would like to clarify or ask?

Thank you so much for participating. Your contributions will be very useful to us in our work.

Appendix C

Coding Instructions

TRU-IT Project

Coding schemes for analyzing trauma resuscitations

In this document, we present two types of coding schemes: (1) medical coding scheme, and (2) control-task and communication coding scheme. We describe the coding schemes, define categories and subcategories and provide instructions on how to do coding using these coding schemes.

The medical coding scheme categorizes a variety of medical tasks and interventions during trauma resuscitations. The control-task and communication coding scheme categorizes tasks and communicative actions performed by the trauma team during trauma resuscitations.

The layout and description of a coding worksheet:

Trauma resuscitations will be videotaped and transcribed. Transcripts will be transferred to a coding worksheet, which will be used for entering codes from both medical and interaction coding schemes.

Table I shows an example from a coding worksheet after the coding has been completed.

LINE #	TIME (ms)	MED CODE	INFO SOURCE CODE	COMM CODE	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
197	<722272>	**B4**	**SEN**	**Q**		**BRE**	TL	(talks to	TEAM)	Chest tube in?
198		**B4**	**SEN**	**DIR**	**JU**	**BRE**	TL	(talks to	JR, CCT, PNR)	Excellent, great! Connect to pleural bag.
199		**B4**		**RLY**		**BRE**	PNR	(talks to	CCT)	Connect it to pleural bag.

Table I: Excerpt from a coding scheme. *Time* is recorded in MS. *"Medical," "Info Source," "Communication," "Metatags"* and *"Mode"* codes are taken from the two coding schemes (represented in Tables III, IV, and V). Codes for *actors* can be found in Table II. *Action* refers to an action performed by the actor. *Subject* refers to a person(s) to whom communication is directed. *Communication* column presents the content of the speech. **NOTE**: There is a time stamp for every vital sign (VS) that gets reported.

For example, the above table can be read as follows: In line 197, a team leader (TL) has asked (Q) the team if they finished inserting the chest tube (B4). In line 198, team leader, based on his observations (SEN = simple sensing: sight) realized that the chest tube is in, praised the team (JU = judgment) and asked them (DIR = directive) to connect the chest tube (B4) to a pleural bag. In line 199, primary nurse (PNR) relays (RLY) this information to the rest of the team.
Note that the *Mode* code for all three lines reads "BRE," which denotes step B in the ATLS protocol (**Bre**athing).

Notice that one communicative action, e.g., as in line 198, can have multiple codes, as long as they belong to different categories or subcategories.

a) TRU Actors: Actors within categories are ordered based on their expertise.

CATEGORY	TEAM MEMBER	CODE
Medical doctors	Attending physician	ATP
	Team leader	TL
	Senior resident	SR
	Anesthesia	ANST
	Junior resident	JR
	Orthopedic	ORT
Nursing staff	Primary nurse	PNR
	Scribe nurse / Recorder	REC
	Critical Care Technician	CCT
Ancillary staff	Pharmacist	PHARM
	Respiratory therapist	RT
	X-rays technician	X-TECH
	Technician (general)	TECH
	Emergency Medical Services	EMS
Patient	Patient	PTN

Table II: Actors and their corresponding codes.

b) TRU Medical Coding Scheme (captures primary and secondary examinations, vital signs, fluids, transfer to another hospital unit, and so on.)

MAIN CATEGORIES	SUBCATEGORIES		CODE
Primary examination	*Airway*	Any assessment of airway patency	A1
		Chin lift/jaw thrust	A2
		Intubation[1]	A3
		Cervical spine immobilization	A4
	Breathing and ventilation	Chest auscultation	B1
		Chest inspection / palpation	B2
		Oxygen saturation	B3
		Respiratory rate	B4
		Administration of oxygen (mask, prongs, etc.) and ventilation	B5
		Chest tube placement and drain	B6
	Circulation	Blood pressure	C1
		Heart rate (pulse)[2]	C2
		Radial, femoral, distal, and carotid pulses[3]	C3
		ECG leads placement and measurement	C4
		Establishment of IV access[4]	C5
		Crystalloid (salt solution) infusion	C6
		Blood transfusion	C7
		Hemorage control (active bleeding)[5]	C8
	Disability	Examination of pupils	D1
		Glasgow Coma Scale score (or AVPU)[6]	D2
		Neurological examination[7]	D3
	Exposure	Full exposure[8]	E1
		Log roll	E2
Secondary examination	Blood draw / blood tests / ABGs / urine tests		S1
	Pelvic palpation / pelvic rock test		S2
	Abdomen palpation & tests for bleeding (FAST, DPL)[9]		S3
	Chest and pelvic x-ray		S4
	Foley catheter for urine output		S5
	Nasogastral (NG) tube placement / OGT tube		S6
	Administering medications, e.g., pain killers		S7
	Placement of skeletal traction & orthopedic procedures[10]		S8
	Rectal / prostate exam		S9
	Temperature measuring & control (blanket)		S10
	Assessments for open wounds, bruises, lacerations		S11
	TMs exam[11]		S12
Transfer (to another hospital unit)	Operating room		OR
	Intensive care unit		ICU
	CT scanning		CT
	Radiology		R
Pre-hospital events	Mechanism of injury		MI
	Patient history		PH

Table III: Medical events and interventions and their corresponding codes.

1 Includes giving medications for anesthesia and detection of CO_2 in exhaled gas.

2 If a team member reports a numeric measurement for pulse, the action code is "Reporting," same as the heart rate. A qualitative assessment "*weak pulse*" is coded as "Assessment."

3 These are felt on touch; when BP is low, you cannot feel them physically; carotid pulse is checked rarely, only if the patient is almost dying.

4 Includes femoral cordis and infuser.

5 Tasks include holding pressure, stapling head, putting pelvic sling, giving plate lits, blood products, etc.

6 Three categories: best eye opening (cannot open eyes, 1; 2 if you open eyes; 4 points if they open eyes spontaneously), best verbal score (no words at all -- 1), motor score (if you don't move at all, 1point) – lowest score 3; e.g., questions such as "What's today's date?" are asked to assess verbal score…

GCS is to check for brain injury – tells words but they don't make any sense = 3; not knowing their name or where they are = 4; normal = 5; we often hear paramedics saying "alert and oriented x 3" (a-and-o-times-three) = highest score, means patients is able to talk and aware of surrounding -- know who they are, where they are and what's today's date; if the team hears this, there is no need to do the rest of GCS

Alternative to GCS is AVPU (assessment of mental status), which stands for Alert Voice Pain Unresponsiveness – we don't hear this at all, but just in case…

7 Motor/sensory exams to check for spinal cord injury – **motor exam for movement**, reflexes, e.g., asking patient if she or he can lift up their leg or arm against gravity, wiggle toes, squeeze hands, etc.; **sensory exam for sensation**, e.g., asking patient if touching feels normal or less than normal

8 Taking the clothes off

9 Includes auscultation of bowel sounds and asking the patient about feeling any tenderness

10 Checking if there are broken legs or arms, bumps, etc.

11 To check if there is blood in ear canal – blood implies there is a scull fracture

c) TRU Control-Task and Communication Coding Scheme

MAIN CATEGORIES		SUBCATEGORIES	CODE
Information acquisition and retrieval	**Observing**	Physical examination (auscultation, palpation)	EXM
		Manual measurement	MM
		Simple sensing: sight, sound, touch, time	SEN
		Instrument reading	IR
	Memory recall & info retrieval	Knowledge recall	LTM
		Situation recall	STM
		Info retrieval from artifacts (trauma flowsheet, notes, x-ray workstation…)	MEXT
Communication & Intervention	**Verbal procedures**	Directives (Task assignment / Instruction / Command)	DIR
		Report (about patient status or team member activity)	RP
		Inquiry / Request for information	Q
		Response to an inquiry or request for information	RS
		Clarification (Request for retransmission of information)	CL
		Relay	RLY
		Acknowledgement	ACK
		Summons	SM
	Nonverbal procedures	Therapeutic intervention / Treatment	INT
		Setting-up instrument/equipment	SET
		Recording information (e.g., on a trauma flow sheet)	RC
		Handing / Receiving an object	HRO
Decision-making	**Skill-based behaviors**	Task coordination	TC
	Rule-based behaviors	Solo decision making	SDM
		Strategic planning	SP
		Judgment: Approval vs. Disapproval vs. Praising	JU (A/D/P)
		Takeover / Handover of leadership role	TO
	Knowledge-based behaviors	Group decision making	GDM
		Coaching / Educating	ED

Table IV: Communicative and non-communicative actions and their corresponding codes. Additional coding conventions: the start of a lengthy task is signified by the "_B" suffix to the main code; continuation suffix is "_C"; termination suffix is "_E." Tasks that are performed by simultaneous effort of several team members are coded by adding the prefix "C_" to the regular code.

d) TRU Modes: Modes and their codes.

MODE	CODE
Airway	AIR
Breathing	BRE
Circulation	CIR
Disability	DIS
Exposure	EXP
Secondary survey	2nd
Vitals	V
Fluids	F
People	P
Procedure	PR
Instrument (measuring)	I
Medications	M
Equipment	E
Patient	PTN

Table V: Modes and their corresponding codes.

In addition to the main interaction coding scheme (presented in Table IV), we use the MODE codes which denote the type of information that is being communicated in inquiries, responses, task assignments, or assertions, as well as the steps in ATLS protocol to which they belong (see Table V).

Appendix D

Intracoder Reliability Statistical Analysis

Intra-coder Reliability for Information Source Subcategories

```
CROSSTABS
  /TABLES=coder1_InfoSource BY coder2_InfoSource
  /FORMAT=AVALUE TABLES
  /STATISTICS=KAPPA
  /CELLS=COUNT
  /COUNT ROUND CELL.
```

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
coder1_InfoSource * coder2_InfoSource	609	100.0%	0	.0%	609	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.697	.022	34.782	.000
	N of Valid Cases	609			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Intra-coder Reliability for Communication Subcategories

```
CROSSTABS
  /TABLES=coder1_Communication BY coder2_Communication
  /FORMAT=AVALUE TABLES
  /STATISTICS=KAPPA
  /CELLS=COUNT
  /COUNT ROUND CELL.
```

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
coder1_Communication * coder2_Communication	609	100.0%	0	.0%	609	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.924	.011	64.096	.000
	N of Valid Cases	609			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Intra-coder Reliability for Decision-Making Subcategories

```
CROSSTABS
  /TABLES=coder1_DecisionMaking BY coder2_DecisionMaking
  /FORMAT=AVALUE TABLES
  /STATISTICS=KAPPA
  /CELLS=COUNT
  /COUNT ROUND CELL.
```

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
coder1_DecisionMaking * coder2_DecisionMaking	609	100.0%	0	.0%	609	100.0%

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.582	.056	22.124	.000
	N of Valid Cases	609			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Appendix E

An Example Transcript

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
1	¤<0>							**START**		
2						**P**	ATP	(in the room)		
3						**P**	EMS1	(in the room)		
4						**P**	CCT1	(in the room)		
5						**P**	CCT2	(in the room)		
6		**MI, PH**	**STM**	**RP_B**		**MI, PH**	EMS1	(talks to	TEAM)	I have young-adult-year old who was driving motorcycle, moderate speed, he was...
7						**P**	TL	(enters room)		
8		**MI, PH**	**STM**	**RP_C**		**MI, PH**	EMS1	(continues report, talks to	TEAM)	... he was actually...
9						**P**	JR	(enters room)		
10								(everybody stands around EMS1 and listen to her report)		
11		**MI, PH, V, F**	**STM**	**RP_C**		**MI, PH, V, F**	EMS1	(continues report, reads from notes, talks to	TEAM)	... he got his helmet stuck underneath the vehicle and had to be air bagged up. His helmet is intact, there are no extreme markings on that. Right now he is complaining of rib pain on the right side, he's got leg pain, possible right hip fractured, he's already got 5 of morphine on board in 16 gauge left AC, allergies to penicillin, no medical history, his sat is at 99%, his O2 sat is 100, glucose is 107, last pressure 145/78, he's got 500 ml amount of fluid in, and ah, basically he is... he also has a right-sided hand tingling, he's not able to move it appropriately.
12	¤<60320>	**B5**		**INT**		**BRE**	EMS2, EMS3	(bring in the PTN, PTN has his helmet on, also has oxygen mask attached to his mouth)		
13						**P**	ANST	(enters room)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
14		**D2**	**STM**	**RP_E**		**D2**	EMS1	(continues report, talks to	TEAM)	He is a & o x 3... and that's pretty much it.
15						**P**	ORT	(enters room)		
16						**P**	EMS4	(enters room)		
17						**P**	?2	(enters room)		
18				**RP**			EMS4	(talks to	ATP)	He's also (unintelligible)
19	¤<70946>					**P**	PNR	(enters room)		
20		**A4**	**SEN**	**Q**	**SDM**	**E, AIR**	?	(talks to	TEAM)	Do we have collar for him?
21				**Q**			ATP	(talks to	EMS4)	(unintelligible)
22				**RS**			EMS1	(talks to	ATP)	(unintelligible)
23		**A4**		**SET**		**E, AIR**	TL	(stands near stretcher, goes to the bench, fetches collar and start preparing it)		
24						**P**	REC	(enters room)		
25						**P**	Spectato r1	(enters room)		
26						**P**	Spectato r2	(enters room)		
27							EMS1	(stands at REC's desk)		
28		**MI**	**SEN**	**Q**		**MI**	ANST	(talks to	EMS1)	(asks something about PTN's helmet, unintelligible)
29		**MI**	**STM**	**RP**		**MI**	EMS1	(talks to	ANST)	He's got his helmet underneath the car... (continues report, gives more details)
30								[at the same time, around PTN:		
31				**SET**		**PTN**	EMS2, EMS3, PNR, CCT2, ORT	(prepare PTN for transfer)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
32	¤<105619>			**Q, DIR**	**TC**	**PR**	EMS2	(talks to	EMS3, PNR, ORT, CCT2)	Ready? One, two, three...
33								(PTN is on the stretcher)]		
34		**MI, PH**		**RP_B**		**MI, PH**	EMS1	(turns to REC, talks to	REC)	(tells the story)
35				**RC**			REC	(writes things down)		
36				**SET**		**E**	EMS3	(takes the bed out)		
37						**P**	PHARM1	(in the room)		
38		**E1**		**SET**	**SDM**	**EXP**	PNR	(cuts the clothes off)		
39		**C4**		**SET**	**SDM**	**E, CIR**	CCT2	(prepares to put EKG leads)		
40		**C1**		**SET**	**SDM**	**E, BRE**	CCT1	(prepares blood pressure cuff for manual BP measurement)		
41		**C6**		**SET**		**E, CIR**	ATP	(adjusts the lines around PTN's left arm)		
42				**Q, RP**		**PR**	TL	(talks to	PTN)	Hi, how are you? Okay? We'll be taking care of you, okay?
43	¤<120689>			**RS**			PTN			(complains about pain in his leg)
44				**RP**		**PR**	TL	(talks to	PTN)	There will be a lot of people working on you, okay?
45		**S11**		**Q**	**SDM**	**S11**	TL	(prepares stethoscope, talks to	PTN)	Which leg, left or right?
46		**S11**		**RS**		**S11**	PTN	(talks to	TL)	(tells more about his pain).
47				**ACK**			TL	(talks to	PTN)	Okay.
48		**S11**		**RS**		**S11**	PTN	(talks to	TL)	(tells more about his pain).

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
49		**B3**		**SET**	**SDM**	**E, BRE**	RT	(takes pulse oximeter, attaches it to PTN's right finger)		
50		**B1**	**EXM_B**			**BRE**	TL	(listen to breath sounds)		
51		**B1**	**EXM**	**DIR**		**BRE**	TL	(talks to	PTN)	Deep breath!
52		**C1**	**MM_B**			**CIR**	CCT1	(measures BP)		
53		**S8**		**SET**	**SDM**	**E, 2ND**	ORT	(removes gauze/cast from PTN's left leg, probably was put there by EMS folks)		
54	¤<151611>	**C1, V**	**EXM_E, SEN**	**Q**		**CIR, V**	TL	(finishes listening to breath sounds, talks to	TEAM)	What's the blood pressure?
55		**B1**	**SEN**	**Q**	**ED**	**BRE**	ATP	(talks to	TL)	Breath sounds were equal bilateral?
56		**B1**	**EXM**	**RS**		**BRE**	TL	(talks to	ATP)	Equal bilateral breath sounds.
57		**MI, PH**		**RP_C**		**MI, PH**	EMS1	(talks to	REC)	(repeats all details from her report, IV access, meds given, initial vitals, etc.)
58		**MI, PH**		**RC**			REC	(writes things down)		
59		**PH**	**MEXT**	**RP_C**		**PH**	EMS1	(talks to	REC)	His name is (gives name).
60		**PH**		**RC**			REC	(writes PTN's name down)		
61		**E1**		**SET_B**	**SDM**	**EXP**	TL	(starts removing helmet from PTN's head)		
62		**B3, C2, V**	**IR**	**RP**		**BRE, CIR, V**	CCT2	(looks at the monitor, talks to	TEAM)	90% oxygen, heart rate 102.
63		**V**		**RC**			REC	(hears CCT1's report, writes the value down)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
64		**C1, V**	**MM_C**			**CIR, V**	CCT1	(finishes BP measurement)		
65	¤<182429>	**C1, V**	**MM**	**RP**		**CIR, V**	CCT1	(turns to REC, but talks out loud, talks to	TEAM)	150 over 70 BP
66		**E1**		**SET**		**EXP**	ATP	(helps remove straps around the PTN)		
67							PTN			(complains about pain)
68				**DIR**		**PTN**	TL	(talks to	PTN)	Relax!
69		**C1, E**	**MM_E**	**SET**		**E, CIR**	CCT1	(removes manual BP cuff and puts away the instrument)		
70		**C1, E**		**SET**		**E, CIR**	CCT2	(prepares automatic BP, places it on PTN's right arm)		
71							ATP	(talks to	ORT)	(unintelligible)
72		**E1**		**SET_C**		**EXP**	TL	(still removing helmet)		
73							PTN			(complains about pain in his arm)
74							ORT	(opens up his cell phone, looks at it, puts it back to his pocket)		
75							TL	(talks to	ATP)	(unintelligible, but possibly he's asking for help to remove the helmet)
76		**A4**	**EXM**	**SET**		**E, AIR**	ATP	(palpates around PTN's neck, helps	TL)	
77		**A4**		**SET**		**E, AIR**	TL	(prepares collar)		
78	¤<219038>						PTN			(complains about the pain in his right arm)

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
79		**S8**	**SEN**	**DIR**	**ED, GDM**	**2ND**	ATP	(looks at the arm and it's position, hanging, and talks to	TEAM)	He's complaining about his arm, so we should be doing something, might be a fracture...
80		**C1, E**		**SET**		**E, CIR**	CCT1	(removes BP cuff from arm in pain)		
81		**S1**		**SET**	**SDM**	**E, 2ND**	PNR	(prepares blood draw toolkit)		
82				**SET**		**PTN**	RT	(puts PTN's arm on the bed)		
83	¤<235947>					**P**	PHARM2	(enters room)		
84		**E1**		**DIR**	**TC_B**	**EXP**	TL	(talks to	ATP, ORT)	(asks for help in removing helmet while holding PTN around his neck)
85		**MI, PH**		**RP_C**		**MI, PH**	EMS1	(reads from her notes, still talks to	REC)	(gives more details about mechanism of injury & patient history)
86		**MI, PH**		**RC**		**MI, PH**	REC	(writes things down)		
87		**E1**		**SET**	**TC_C**	**EXP**	ORT	(removes helmet while TL is holding PTN's head)		
88								(accidentally, ORT hits TL's nose and chin with PTN's helmet, laughs)		
89				**HRO**	**TC_E**		ORT	(gives helmet to	CCT2)	
90		**A4**		**INT_B**		**AIR**	ATP	(places collar around PTN's neck)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
91		**S1**		**INT_B**		**2ND**	PNR	(prepares PTN's left arm for blood draw)		
92		**C1, E**		**SET**		**E, CIR**	CCT1	(places automatic BP cuff on PTN's left arm)		
93							CCT2	(takes the helmet out of the room)		
94							PTN			(complains about pain in his leg)
95	¤<274194>							(18 people in the room at this point)		
96		**S8**		**SET_B**		**2ND**	ORT	(takes green bucket with cast and other equipment, starts preparing cast)		
97		**S11**	**EXM**	**RP**		**2ND**	JR	(stands at the foot of the bed, turns to REC, talks to	REC)	Laceration on the left knee.
98		**S11**		**RC**		**S11**	REC	(writes things down)		
99							PHARM	(talks to	EMS1)	Hey, how are you?
100							EMS1	(nods, talks to	PHARM)	(unintelligible)
101		**A4**		**INT_E**		**AIR**	TL	(finishes putting collar around PTN's neck, adjusts it so that it holds well)		
102		**S1**		**INT_C**		**2ND**	PNR	(still taking blood)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
103						**P**	ANST	(approaches REC's desk, shows his badge to	REC)	
104				**RC**		**P**	REC	(writes down his name on the flow sheet)		
105						**P**	ANST	(leaves the room)		
106	¤<289922>			**Q**	**ED**	**PR**	ATP	(talks to	JR)	Alright, (name), what have you got so far?
107			**EXM**	**RS**		**PR**	JR	(stands on the right side of the PTN, talks to	ATP)	(unintelligible)
108				**Q**	**ED**	**PR**	ATP	(talks to	JR)	Did you tell it anybody?
109				**RS**		**PR**	JR	(talks to	ATP)	No.
110		**C1, E**		**SET**		**E, CIR**	CCT1	(connects the BP cuff to the monitor)		
111				**Q**	**ED**	**PR**	ATP	(talks to	JR)	Have you checked upper extremities?
112			**EXM**	**RS**		**PR**	JR	(talks to	ATP)	(unintelligible, gives some details)
113				**ACK, Q**	**ED, SDM**	**PR**	ATP	(talks to	JR)	Okay, what about femoral and radial?
114	¤<315072>	**D1**		**SET**	**SDM**	**E, DIS**	TL	(reaches for pen light)		
115		**D1**	**EXM_B**			**DIS**	TL	(examines PTN's eyes)		
116		**S12**	**EXM_C**			**2ND**	TL	(examines PTN's ears)		
117		**C3**	**EXM**			**CIR**	JR	(palpates around, checks for femoral and radial pulses)		
118						**P**	RT	(leaves the room)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
119		**C3**	**EXM**	**RP**		**CIR**	JR	(speaks out loud, talks to	REC)	2+ femoral pulse bilaterally.
120		**S12**	**EXM**	**RP**		**2ND**	TL	(talks to	TEAM)	TMs clear!
121		**C3**	**EXM**	**RP**		**CIR**	JR	(still palpating PTN's legs, talks to	TEAM)	(unintelligible, but reporting about pulses on the right and left legs)
122		**C1, V**	**SEN**	**Q**	**TO**	**CIR, V**	ATP	(talks to	CCT1)	Did you get the blood pressure yet?
123	¤<345668>	**C1, V**	**STM**	**RS**		**C1, V**	CCT1	(talks to	ATP)	Yeah, I got 150 over 70 manually, but we are gonna do this one [automatic] once he [points to PNR] is done with this blood draw.
124		**C1, V**	**STM**	**RS**		**C1, V**	EMS2	(talks to	CCT1)	That's what we were getting in the field.
125		**S1**		**INT_C**		**2ND**	PNR	(while still taking blood, talks to	CCT1)	You can get it.
126		**C3**	**EXM**	**RP**		**CIR**	JR	(talks to	ATP)	2+ radial bilaterally.
127		**C3**		**RC**		**CIR**	REC	(writes things down)		
128		**S8**		**SET_C**		**2ND**	ORT	(still preparing cast)		
129		**S12**	**EXM_E**	**RP**		**2ND**	TL	(finished examining ears, talks to	TEAM)	There is a little of blood in the left, right ear, but I don't think it's coming from inside.
130	¤<365331>	**D1**	**EXM**	**RP**		**2ND**	TL	(returns the pen light, turns to the team, talks to	ATP)	Pupils bilaterally reactive, about 3mm reactive both.
131		**C3**	**SEN**	**Q**		**CIR**	TL	(talks to	JR)	All (unintelligible), (name)?
132		**C3**	**EXM**	**RS**		**CIR**	JR	(talks to	TL)	Yes.
133							TL	(talks to	JR)	(unintelligible)
134		**D3**	**EXM**	**Q**		**DIS**	TL	(talks to	PTN)	Can you move your fingers at all?
135								(PTN reacts)		
136		**D3**	**EXM**	**Q**		**DIS**	TL	(talks to	PTN)	You feel tingling (unintelligible)?
137								(PTN responds)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
138		**D3**	**EXM**	**Q**		**DIS**	TL	(moves to the PTN's right side, talks to	PTN)	Can you bend the elbows?
139		**S10**		**SET**	**SDM**	**2ND**	CCT1	(takes the blanket from the closet)		
140	¤<390879>	**C1, C2, B3, V**	**IR**	**RP**		**CIR, BRE, V**	CCT1	(talks to	TEAM)	BP 158 over 87, hear rate 96, sat 99%.
141		**D3**	**EXM**	**Q**		**DIS**	TL	(touches PTN's hand)		Can you feel this?
142								(PTN responds)		
143		**D3**	**EXM**	**Q**		**DIS**	TL	(talks to	PTN)	No? What do you feel?
144								(PTN responds)		
145		**S10**		**INT**		**2ND**	CCT1	(covers PTN with blanket)		
146		**D3**	**EXM**	**ACK**		**DIS**	TL	(talks to	PTN)	(unintelligible), okay!
147		**DR**	**EXM**	**DIR**		**DIS**	TL	(points toward PTN's feet, talks to	JR)	(unintelligible)
148		**D3**	**EXM**	**Q**		**DIS**	TL	(talks to	PTN)	Can you move your toes?
149		**D3**	**EXM**	**Q**		**DIS**	JR	(talks to	PTN)	Can you move your toes?
150								(phone/beeper rings)		
151							TL	(takes his beeper out, checks it, puts it back to his pocket)		
152	¤<415998>	**E2**	**SEN**	**DIR**	**TO, SDM, SP**	**EXP**	ATP	(talks to	TEAM)	Okay, as soon as the IV is secured, let's roll him!
153		**C5, S1**	**SEN**	**Q**		**CIR, 2ND**	TL	(talks to	PNR)	Are you ready?

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
154		**C5, S1**	**SEN**	**RS**		**CIR, 2ND**	PNR	(still taking blood, setting IV, talks back to	TL)	Yeah, let me just secure this IV and I am done.
155		**E2**	**SEN**	**DIR**	**TC_B**	**EXP**	TL	(points toward left, talks to	TEAM)	Alright, we're gonna go that way.
156		**S8**		**SET_C**		**2ND**	ORT	(still preparing cast)		
157	¤<442937>					**P**	EMS2, EMS3	(leave the room)		
158		**S4**		**SET**		**E, 2ND**	X-TECH1	(enters room with x-ray plates)		
159		**C5, S1**		**INT_E**		**CIR, 2ND**	PNR	(finishes blood draw and IV access setup)		
160							TL	(moves the stretcher to the left, lines are tight)		
161							TL	(talks to	JR)	(asks for help in moving stretcher)
162		**E2**		**RP**	**SP**	**PTN**	TL	(talks to	PTN)	We are going to roll you on your left to take this board off you, we are done, okay?
163							PTN	(responds)		
164	¤<456553>	**S1**		**SET**		**2ND**	PNR	(brings blood samples to	REC)	
165		**S8**	**SEN**	**Q**	**TC_C**	**2ND**	TL	(talks to	ORT)	You got the leg?
166		**S8**	**SEN**	**RS**		**2ND**	ORT	(talks to	TL)	Yeah.
167		**E2**	**SEN**	**DIR**	**ED, TC_C**	**EXP**	TL	(points to his side, talks to	JR)	You will come on this side, okay?
168		**E2**	**LTM**	**DIR**	**ED, TC_C**	**EXP**	TL	(moves to the top of the bed, talks to	JR)	Carefully watch as we roll him, take the board out first, and all the clothes and everything, and then you're gonna do his spine, and then the rectal, alright?
169		**E2**		**ACK**		**EXP**	JR	(nods to	TL)	
170						**P**	EMS1	(leaves the room)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
171		**E2**		**SET**	**TC_C**	**P**	CCT1, JR, PNR, TL	(prepare for log roll)		
172							ORT	(talks to	ATP)	(unintelligible)
173							ATP	(talks to	ORT)	(unintelligible)
174		**S8**	**SEN**	**Q**		**2ND**	TL	(talks to	ORT)	You got the leg?
175	¤<495745>	**E2**		**DIR**	**TC_C**	**EXP**	TL	(talks to	CCT1, PNR, ORT, JR)	One, two, and three
176								(PTN is rolled)		
177				**SET**		**E**	JR	(takes the board out)		
178				**SET**		**E**	ATP	(helps with the board)		
179				**SET**		**E**	?2	(takes the board out of the room)		
180		**E1**		**SET**	**TC_C**	**EXP**	TL, X-TECH1	(take the jacket underneath the PTN out)		
181		**E2**	**EXM**	**Q**		**EXP**	JR	(goes down the PTN's spine, talks to	PTN)	Do you have any pain here sir, where I am pressing?
182							PTN			(responds)
183		**S4**		**SET_B**		**E, 2ND**	X-TECH1	(puts the x-ray plate below the PTN)		
184	¤<522201>	**E2**	**EXM**	**Q**		**EXP**	JR	(still going down the PTN's spine, talks to	PTN)	Down here, where I am pressing?
185							PTN			(responds)
186		**S11**	**EXM**	**RP**		**2ND**	ATP	(talks to	REC)	He has open lacerations on the right leg.
187				**OTH**			REC	(puts labels on blood tubes)		
188		**S4**		**SET_C**		**E, 2ND**	X-TECH2	(brings in x-ray machine)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
189		**E2**	**EXM**	**RP**		**EXP**	JR	(talks to	TEAM)	Okay, no step offs!
190							TL	(talks to	PTN)	(calms him down)
191		**S9**		**RP**		**PTN**	JR	(talks to	PTN)	You are gonna feel some pressure sir!
192							PTN	(talks to	JR)	Where? In my butt?
193		**S9**		**ACK**		**2ND**	JR	(talks to	PTN)	Yes!
194		**S9**	**EXM**			**2ND**	JR	(does rectal exam)		
195		**S9**	**EXM**	**RP**		**2ND**	JR	(talks to	TEAM)	No gross blood, good tone.
196				**RC**			REC	(writes down things she heard from ATP and JR)		
197	¤<541457>	**S9**	**SEN**	**Q**	**ED**	**2ND**	ATP	(talks to	JR)	Are we actually doing the rectal exam properly? You need to look for the following things during the exam…
198		**S9**	**LTM**	**RS**		**2ND**	JR	(talks to	ATP)	(unintelligible)
199		**E2**		**DIR**	**TC_E**	**EXP**	TL	(talks to	PNR, CCT1)	One, two and three... let's go back slowly.
200								(PTN cries because of pain in his leg)		
201	¤<555409>	**S7**	**SEN, LTM**	**DIR, Q**	**SDM**	**M, 2ND**	TL	(talks to	PHARM)	Can we give him some morphine? Do we have morphine on the board?
202		**S7**	**STM**	**RS**		**M, 2ND**	PHARM	(talks to	TL)	He had it in the field.
203		**S7**	**SEN**	**Q**		**M, 2ND**	TL	(talks to	PHARM)	Nothing here?
204		**S7**	**SEN**	**RS**		**M, 2ND**	PHARM	(talks to	TL)	No.
205		**S7**	**LTM**	**DIR**		**M, 2ND**	TL	(talks to	PHARM)	We can give him some morphine.
206		**S7**	**SEN**	**Q**		**M, 2ND**	PHARM	(talks to	TL)	(asks about amount of meds given)
207		**S7**	**LTM**	**DIR**	**SDM**	**M, 2ND**	TL	(talks to	PHARM)	Give him increments of 2 mg of morphine

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
208		**S7**		**ACK**		**M, 2ND**	PHARM	(talks to	TL)	Okay.
209		**S7**		**HRO**		**M, 2ND**	PHARM	(has medication in his hands, hands it over to	PNR)	
210		**S7**		**HRO**		**M, 2ND**	PNR	(setting up the lines, takes the meds from	PHARM)	
211	¤<575237>	**S7**	**SEN**	**Q**		**M, 2ND**	PNR	(talks to	TL)	How much do you want?
212		**S7**	**LTM**	**RS**		**M, 2ND**	TL	(talks to	PNR)	Start with 3 mg, increments of 2mg
213		**S4**		**SET_C**		**E, 2ND**	X-TECH1	(sets up the x-ray machine)		
214		**C6, F**		**SET, HRO**	**SDM**	**F, CIR**	PNR	(goes to the glass cabinet, takes a bag of fluid, gives it to	CCT1)	
215		**C6, F**		**SET, HRO**		**F, CIR**	CCT1	(hangs up the bag of fluid)		
216		**S4**		**RP**		**2ND**	X-TECH1	(talks to	TEAM)	X-ray!
217		**S7**		**INT**		**M, 2ND**	PNR	(administers medication through IV access)		
218								(everybody leaves the room)		
219		**S4**	**MM**			**2ND**		(x-rays taken)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
220		**C6**		**INT**		**CIR**	PNR	(enters room, goes straight to the patient, connects the IV access with fluid bags)		
221	¤<630511>	**C5**	**SEN**	**SM, Q**		**E, CIR**	REC	(talks to	PNR)	Hey, (name), what size did you put in the other hand?
222		**C5**	**STM**	**RS**		**E, CIR**	PNR	(talks to	REC)	About an 18?
223		**C5**		**RC**		**E, CIR**	REC	(writes this down)		
224		**S4**		**SET_C**		**E, 2ND**	X-TECH1	(takes the x-ray plate out, puts another one below pelvis)		
225								(outside the room, we can hear TL, ATP and some other people talking)		
226							REC	(looks for something in the glass cabinet, leaves the room)		
227		**S8**		**SET_C**		**2ND**	ORT	(brings in green buckets full of water)		
228		**S4**		**SET_C**	**TC**	**E, 2ND**	PNR	(helps to X-TECH to place the x-ray plate)		
229								(everybody leaves the room)		
230		**S4**	**MM**			**2ND**		(x-rays taken)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
231						**P**	ORT	(enters room again)		
232						**P**	TL	(enters room again)		
233		**S4**		**SET_C**		**E, 2ND**	X-TECH1. X-TECH2	(take the x-ray plate out)		
234	¤<705174>	**S8**	**LTM**	**DIR**	**TO, SDM**	**2ND**	ORT	(talks to	X-TECH1)	Can we take an x-ray of his leg?
235		**S8**	**SEN**	**CL**		**2ND**	X-TECH1	(talks to	ORT)	You wanna take it now?
236		**S8**	**SEN**	**RS**		**2ND**	ORT	(talks to	X-TECH1)	Yes.
237						**P**	PNR	(comes back to room)		
238						**P**	ATP	(comes back to room)		
239						**P**	PHARM	(comes back to room)		
240			**IR**				TL	(looks at the monitor)		
241		**S4**		**SET_C**		**E, 2ND**	X-TECH1	(talks to	X-TECH2)	Can you give me another plate?
242		**S4**		**HRO**		**E, 2ND**	X-TECH2	(gives x-ray plate to	ORT)	
243		**S4**		**HRO**		**E, 2ND**	ORT	(passes x-ray plate to	X-TECH1)	
244		**S4**		**RP**	**JU/D**	**2ND**	ATP	(talks to	ORT)	(unintelligible)
245		**S4**		**RP**		**2ND**	ORT	(talks to	ATP)	(unintelligible)
246		**S7**		**SET**		**M, 2ND**	PHARM	(takes meds from the fridge)		
247							PNR	(approaches	PHARM)	(unintelligible)
248		**S7**		**HRO**		**M, 2ND**	PHARM	(hands med to	PNR)	

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
249		**S7**		**SET**		**M, 2ND**	PNR, PHARM	(check something about the med)		
250		**S4**		**SET_C**		**E, 2ND**	X-TECH1	(places x-ray plate under PTN's right leg)		
251							PTN			(complains about breathing problems)
252			**IR**				TL	(looks at the monitor, talks to	PTN)	(unintelligible)
253		**S3**		**SET**		**E, 2ND**	TL	(prepares FAST machine)		
254				**OTH**			EMS1	(enters room, asks REC to sign some document)		
255				**OTH**			REC	(signs the doc)		
256	¤<746515>	**S4**	**SEN**	**Q**	**GDM_B**	**2ND**	X-TECH1	(refers to position of the plate, talks to	ORT)	Do you wanna oblique like that or you want...
257		**S4**	**LTM**	**RS**	**GDM_E**	**2ND**	ORT	(talks to	X-TECH1)	I just want general idea of what's going on.
258		**S7**		**RP**	**SDM**	**M, 2ND**	PNR	(talks to	PTN)	I am giving you a tetanus.
259		**S7**		**INT**		**M, 2ND**	PNR	(administer tetanus)		
260		**S4**		**RP**		**2ND**	X-TECH1	(talks to	TEAM)	X-ray!
261		**S1**		**OTH**		**2ND**	REC	(collects bags with blood samples, leaves the room)		
262								(everybody leaves the room)		
263		**S4**	**MM**			**2ND**		(x-rays taken)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
264		**S4**		**SET_C**		**E, 2ND**	X-TECH1	(removes x-ray machine, takes the plate out)		
265		**S3**		**SET**	**SDM**	**E, 2ND**	TL	(gets FAST machine closer, starts putting gel on PTN's stomach)		
266		**S1**		**OTH**		**2ND**	PNR	(enters room with a blood paperwork, writes something down)		
267		**S1**		**OTH**		**2ND**	REC	(signs blood paperwork, puts it in one of the bags with blood samples)		
268		**S4**		**SET_E**		**E, 2ND**	X-TECH1	(takes the x-ray machine out of the room)		
269	¤<799536>	**V**	**SEN**	**SM, DIR**	**TO**	**V**	REC	(talks to	CCT1)	(Name), can we get some more vitals?
270		**V**		**SET**		**E, V**	CCT1	(goes to the vital signs monitor, does something to, sounds like he turns it on?)		
271		**PH**	**SEN**	**Q**		**PH**	ORT	(approaches PTN, talks to	PTN)	What's your first name?
272								(PTN responds)		
273		**D3**	**EXM**	**DIR**		**DIS**	ORT	(talks to	PTN)	Listen, do me a favor, squeeze my hand! Thumbs up real strong! Hold it up! Spread your fingers real wide! Excellent.

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
274	¤<817748>	**S3**	**EXM_B**			**2ND**	TL	(starts FAST exam)		
275		**S7**	**STM**	**RP**		**M, 2ND**	PHARM	(talks to	REC)	(tells about the administered medications)
276		**S7**		**RC**		**M, 2ND**	REC	(writes things down)		
277		**S11**	**EXM**	**Q**		**2ND**	ORT	(moves to the other side of the patient, palpates PTN around neck and shoulder, talks to	PTN)	Where is you pain?
278								(PTN responds)		
279		**S11**	**EXM**	**CL**		**2ND**	ORT	(talks to	PTN)	On the shoulder?
280								(PTN responds)		
281		**S11**	**EXM**	**CL**		**2ND**	ORT	(talks to	PTN)	Right here?
282								(PTN responds)		
283		**D3**	**EXM**	**DIR**		**DIS**	ORT	(moves to the PTN's hand, talks to	PTN)	Can you squeeze my fingers hard?
284								(PTN reacts)		
285		**S3**		**OTH**		**2ND**	ATP	(approaches TL, watches him as he does FAST exam)		
286	¤<830953>	**S8**	**EXM**	**DIR**		**DIS**	ORT	(talks to	PTN)	Can you spread you fingers out?
287								(PTN reacts)		
288		**S8**	**EXM**	**DIR**		**DIS**	ORT	(demonstrates bending wrist, talks to	PTN)	Can you do this?
289								(PTN reacts)		
290		**S8**	**EXM**	**DIR**		**DIS**	ORT	(demonstrates bending wrist, talks to	PTN)	Now do this? Hold up! Real strong!

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
291	¤<847247>	**C1, C2, B3, V**	**IR**	**RP**		**CIR, BRE, V**	CCT1	(looks at the monitor, talks to	TEAM)	BP 150 over 85, pulse 92, and sat 98%
292		**C1, C2, B3, V**		**ACK**		**CIR, BRE, V**	REC	(writes something in the red book, but acknowledges CCT1's report, talks to	CCT1)	Okay.
293		**D3**	**EXM**	**Q**		**DIS**	ORT	(palpates PTN's hand, talks to	PTN)	Do you feel me touching? How does this feel? This one feels normal? This one?
294	¤<882288>	**C1, C2, B3, V**		**RC**		**CIR, BRE, V**	REC	(returns the red book, writes down the values she heard, reaches out trying to read some from the monitor, writes things down)		
295		**D3**	**EXM**			**DIS**	ORT	(still examines patient hand)		
296		**S10**	**SEN**	**SM, Q**		**2ND**	REC	(talks to	CCT1)	(Name), you did temperature?
297		**S10**	**STM**	**RS**	**SDM**	**2ND**	CCT1	(talks to	REC)	Probably I did, but I'll do it again, I don't remember what it was.
298		**S10**		**SET**		**E, 2ND**	CCT1	(takes thermometer, measures temperature)		
299							Nurse	(enters room, approaches REC, talks to	REC)	(sounds like she is saying that PTN's family is either on the phone or in the ER)
300							REC	(talks to	Nurse)	Okay, thanks.

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
301	¤<900926>	**S10**	**MM**	**RP**		**2ND**	CCT1	(talks to	REC)	96.1
302		**S10**	**MM**	**RLY**		**2ND**	ATP	(repeats)		96.1
303						**P**	REC	(leaves the room for a moment)		
304		**S3**	**EXM_C**			**2ND**	TL	(still doing FAST)		
305		**D3**	**EXM**	**Q**		**DIS**	ORT	(still examining shoulder, arm, hand, talks to	PTN)	Is it sharp or dull?
306		**S3**	**EXM_E**			**2ND**	TL	(finishes FAST)		
307		**S10**		**RC**		**2ND**	REC	(comes back to the room, writes temp down)		
308	¤<917496>	**S3**	**EXM**	**RP**		**2ND**	TL	(talks to	TEAM)	FAST negative.
309		**D3**	**EXM**	**DIR**		**DIS**	ORT	(moves to patient's feet, talks to	PTN)	Move your toes for me!
310								(PTN reacts)		
311		**D3**	**EXM**	**Q**		**DIS**	ORT	(examines feet, talks to	PTN)	Do you have any pain over here?
312								(PTN reacts)		
313		**D3**	**EXM**	**Q**		**DIS**	ORT	(examines feet, talks to	PTN)	You feel me touching you here?
314								(PTN reacts)		
315		**D3**	**EXM**	**DIR**		**DIS**	ORT	(examines feet, talks to	PTN)	Move ankle up and down.
316								(PTN reacts)		
317		**S8**	**EXM**	**Q**		**DIS**	ORT	(examines leg, talks to	PTN)	Good. Are you having any pain in this thigh?
318								(PTN reacts)		
319		**S8**	**EXM**	**Q**		**DIS**	ORT	(shakes patient legs)	PTN)	Does it feel okay when I move?
320								(PTN reacts)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
321		**S7**		**SET**		**M, 2ND**	PHARM	(attaches med to the IV pole)		
322		**S8**	**EXM**	**Q**		**DIS**	ORT	(moves patient leg up and down)	PTN)	No pain? And hip feels okay?
323		**S2**	**EXM**			**2ND**	ORT	(examines pelvis)		
324		**S3**		**SET**		**P**	TL	(removes gel from patient stomach)		
325							ATP	(talks to	ORT)	(unintelligible)
326							ORT	(talks to	ATP)	(unintelligible)
327	¤<955266>	**S2**	**EXM**	**RP**		**2ND**	ORT	(talks to	TEAM)	Pelvis is stable.
328		**S8**	**SEN**	**DIR**	**TO**	**2ND**	ORT	(talks to	?2)	Let's bandage him!
329	¤<959179>							**PART 1 STOPS HERE**		
330	¤<83822>							**PART 2 STARTS HERE**		
331				**OTH**			PNR	(attaches patient ID to PTN's right hand)		
332		**S4**	**IR**			**2ND**	ATP	(approaches x-rays workstation, starts looking for x-rays)		
333		**S8**		**SET_C**		**2ND**	ORT, ?2	(start preparing cast)		
334		**S8**	**LTM**	**Q**	**GDM_B**	**2ND**	?2	(talks to	ORT)	Do you wanna wrap or...
335		**S8**	**LTM**	**RS**	**GDM_E**	**2ND**	ORT	(points to something in the glass cabinet, talks to	?2)	(unintelligible)

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
336		**S8**		**SET_C**		**2ND**	?2	(takes something from the glass cabinet)		
337		**?**		**Q**		**?**	ATP	(talks to	REC)	(it's a question, but unintelligible)
338							PHARM	(talks to	REC)	(unintelligible)
339	¤<96155>	**CT**	**SEN**	**Q**	**TO, SDM**	**E**	CCT1	(talks to	TL)	Alright, you want me to put him on monitor?
340		**CT**	**SEN**	**RS**		**E**	TL	(nods, talks to	CCT1)	Sure.
341		**CT**		**SET**		**E, PTN**	CCT1	(starts preparing portable monitor)		
342		**S4**	**IR**		**GDM**	**2ND**	ATP	(while looking at the x-rays, talks to	TL)	I have feelings he (unintelligible)
343		**CT**	**SEN**	**Q**	**SDM**	**CT**	TL	(approaches REC, talks to	REC)	Did you call the CAT scan?
344		**S8**		**HRO**		**M, 2ND**	PHARM	(hands another dose of medication to	PNR)	
345		**S8**		**HRO, CL**		**M, 2ND**	PNR	(talks to	PHARM)	(confirms medication)
346		**CT**		**OTH**		**CT**	REC	(makes a phone call to CAT scan)	CAT)	
347		**S8**		**INT_B**		**2ND**	ORT, ?2	(put cast)		
348							PTN	(complains about the pain)		
349		**S7**		**INT**		**M, 2ND**	PNR	(administer medication)		
350	¤<123249>	**PH**	**SEN**	**Q**		**PH**	JR	(talks to	PTN)	Sir, do you have any medical problems?
351								(PTN responds)		
352		**PH**	**SEN**	**Q**		**PH**	JR	(talks to	PTN)	Are you taking any medications?
353								(PTN responds)		
354		**PH**	**SEN**	**Q**		**PH**	JR	(talks to	PTN)	No? Do you have allergies?

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
355								(PTN responds)		
356		**CT**		**RP**		**CT**	REC	(finishes phone call, talks to	TEAM)	CAT scan's ready!
357		**CT**		**SET**		**E, PTN**	CCT1, PNR	(prepare patient for transfer, portable monitor setup, portable IV poles, etc.)		
358				**RC**			REC	(writes some things down)		
359		**PH**	**SEN**	**Q**		**PH**	JR	(talks to	PTN)	(asks more questions re medical history)
360								(PTN responds)		
361		**PH**		**Q**		**OTH**	Security	(approaches REC, talks to	REC)	(asks about patient belongings and if there is anything left in the room)
362		**PH**		**RS**		**OTH**	REC	(talks to	Security)	No.
363	¤<186026>	**S11**	**EXM**	**SM, Q**	**GDM_B**	**2ND**	TL	(looks at the knee injury, talks to	ATP)	Hey, (name), this one here has (?) superficial... (asks some questions about the injury, but unintelligible)
364		**S11**	**EXM**	**RS**	**GDM_E**	**2ND**	ATP	(looks at the injury, talks to	TL)	(unintelligible)
365				**OTH**			PNR	(brings PTN's robe, covers the PTN)		
366		**?**		**DIR**		**?**	TL	(talks to	TEAM)	Get a (stroll?) here!
367		**S4**	**IR**			**2ND**	ATP	(looks up the x-rays)		
368		**S7**		**SET**		**M, 2ND**	PHARM	(attaches another dose of med to IV pole)		
369	¤<251176>	**CT**	**SEN**	**Q**		**CT**	CCT1	(talks to	REC)	(Name), how much time do we have, ten minutes, five minutes?
370		**CT**	**STM**	**RS**		**CT**	REC	(talks to	CCT1)	Ten.

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
371				**OTH**			REC	(wraps up her write-up, folds the flow sheet, leaves it on the table)		
372		**S8**		**INT_C**		**2ND**	ORT, ?2	(still working on the cast)		
373		**D3**	**EXM**	**Q**		**DIS**	ORT	(talks to	PTN)	Do you feel me touching your toes down there?
374								(PTN responds)		
375		**D3**	**EXM**	**ACK**		**DIS**	ORT	(talks to	PTN)	Beautiful.
376				**OTH**			REC	(attaches something to PTN's hand)		
377		**S4**	**IR**			**2ND**	ATP	(still at the x-rays workstation)		
378		**S4**	**IR**		**GDM**	**2ND**	TL	(stops by, looks at the images, talks to)	ATP)	(brief discussion)
379		**S7**			**GDM**	**M, 2ND**	JR, PNR			(discuss PTN's tetanus shot)
380		**S7**	**SEN**	**DIR**	**SDM**	**M, 2ND**	TL	(talks to	PNR)	Just give it to him.
381							PNR	(talks to	PTN)	Did you go the school here in NJ?
382								(PTN responds)		
383		**S7**	**SEN**	**RP**		**M, 2ND**	PNR	(talks to	TL)	Then he had to get it to go to school.
384		**S11**		**INT_B 1**	**SDM**	**2ND**	TL	(takes care of the knee injury)		
385						**P**	REC	(leaves the room, talks to	TEAM)	(unintelligible)
386	¤<334061>	**S7**		**RC**		**M, 2ND**	PHARM	(approaches REC's desk, opens the flow sheet, writes something down)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
387		**S8**		**INT_C**		**2ND**	ORT, ?2	(still putting the cast)		
388		**S11**		**INT_C 1**		**2ND**	TL	(still working on the knee injury)		
389		**S8**		**INT_C**		**2ND**	CCT1	(holds PTN's leg while ORT puts cast)		
390		**S8**		**DIR**		**2ND**	ORT	(talks to	?2)	(asks for some stuff from the green bucket)
391		**S8**		**HRP**		**2ND**	?2	(hands it to	ORT)	
392		**S4**	**IR**			**2ND**	ATP	(finishes with viewing x-rays)		
393				**OTH**			ATP	(looks at the pager)		
394		**S11**		**INT_B 1, DIR**		**2ND**	TL	(asks for gauze or something, talks to	PNR)	Hey, name, can you hand me (?)?
395		**S11**		**HRO**		**2ND**	PNR	(gives stuff to	TL)	
396		**S8**		**INT_C, SET**		**2ND**	?2	(anticipates ORT's next move, fetches some tape for the cast, comes back to ORT)		
397		**S8**		**INT_C, DIR**		**2ND**	ORT	(talks to	?2)	Some tape here...
398		**S8**		**HRO**		**2ND**	?2	(gives tape)		
399	¤<429375>	**S7**		**HRO**		**M, 2ND**	PHARM	(hands medication to	PHARM2)	
400						**P**	PHARM	(leaves the room)		
401		**S8**		**INT_E**		**2ND**	ORT	(finishes putting the cast, talks to	CCT1, ?2)	That's it, alright.
402		**S8**		**SET**		**E, 2ND**	CCT1	(takes the green buckets out of the room)		

Line #	TIME (ms)	MED CODE	INFO SOURCE	TASK	METATAG	MODE CODE	ACTOR	ACTION	SUBJECT	COMMUNICATION
403		**S8**	**IR**		**GDM**	**2ND**	ATP, ORT	(look at the x-rays)		(some discussion, unintelligible)
404		**S8**	**IR**			**2ND**	TL	(approaches x-rays workstation too, looks at the x rays)		
405		**CT**		**SET**		**E, PTN**	CCT1, PNR, JR	(final preps for PTN's transfer)		
406		**CT**	**SEN**	**Q**		**CT**	PNR	(talks to	TEAM)	Did we call CAT scan?
407		**CT**	**STM**	**RS**		**CT**	CCT1	(talks to	PNR)	Yes, we called CAT scan.
408		**CT**	**STM**	**RS**		**CT**	PHARM2	(talks to	PNR)	Yes, we did.
409		**CT**	**SEN**	**DIR**		**CT**	PNR	(talks to	TEAM)	Alright, let's go.
410				**OTH**			PHARM	(has the flow sheet and medication in her hands)		
411				**OTH**			PNR	(looks for medication but then notices PHARM2 has it)		
412						**P**		(PTN leaves the room)		
413	¤<537874>							**THE END**		

Curriculum Vitae

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Education

2009	PhD in Communication, Information and Library Studies, Rutgers, The State University of New Jersey, USA
2005	MLIS in Library and Information Science, Rutgers, The State University of New Jersey, USA
2001	BA in Film & TV Production, Faculty of Drama Arts, University of Belgrade, Serbia

Experience

2009—2008	Graduate Research Assistant, School of Communication & Information, Rutgers, The State University of New Jersey, USA
2008, 2007	User Experience Research Intern, Google, Inc., Mountain View, CA/Kirkland, WA, USA
2008—2006	Teaching Assistant, School of Communication & Information, Rutgers, The State University of New Jersey, USA
2005, 2004	User Experience Research Intern, SIEMENS Corporate Research, Inc., Princeton, NJ, USA
2006—2004	Graduate Research Assistant, School of Communication & Information, Rutgers, The State University of New Jersey, USA
2004—2001	Graduate Research Assistant, Center for Advanced Information Processing (CAIP), Rutgers, The State University of New Jersey, USA

Selected Publications

Refereed Full Conference Papers

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