Information Handover in Time-Critical Work

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ABSTRACT
Information transfer under time pressure and stress often leads to information loss. This paper studies the characteristics and problems of information handover from the emergency medical services (EMS) crew to the trauma team when a critically injured patient arrives to the trauma bay. We consider the characteristics of the handover process and the subsequent use of transferred information. Our goal is to support the design of technology for information transfer by identifying specific challenges faced by EMS crews and trauma teams during handover. Data were drawn from observation and video recording of 18 trauma resuscitations. The study shows how EMS crews report information from the field and the types of information that they include in their reports. Particular problems occur when reports lack structure, continuity, and complete descriptions of treatments given en route. We also found that trauma team members have problems retaining reported information. They pay attention to the items needed for immediately treating the patient and inquire about other items when needed during the resuscitation. The paper identifies a set of design challenges that arise during information transfer under time pressure and stress, and discusses characteristics of potential technological solutions.

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

General Terms
Design, Human Factors.

Keywords
Teamwork, information handover, communication, time-critical work, healthcare, traumatic injury, design challenges.

1. INTRODUCTION
Communication is an essential component of medical work. Successful patient care requires not only diagnosis and treatment but also the ability to communicate critical patient information among healthcare providers. Handover of clinical information occurs in many different contexts. Information is exchanged among nurses or physicians during shift changes, and between wards or institutions. While handovers among nurses and physicians have been studied in depth [4],[8],[21],[24], few studies have looked at handovers between healthcare providers from different disciplines [11],[18]. One type of clinical handover that has been understudied from the perspective of human-human interaction is the information transfer between emergency medical services (EMS) crews and hospital medical staff during trauma resuscitation. Additionally, studies of clinical handover have focused on the quality of the handover process and ignored the subsequent use of transferred information. Understanding how and when transferred information is used and identifying the obstacles faced will allow for greater improvements in the information handover process.

Trauma is the leading cause of death among children and young adults. In the U.S. alone, trauma accounted for more than half a million injuries and about 22 thousand deaths in 2007 [12]. Because early care after a traumatic injury has an important impact on the outcome, initial management of the injured patient ("trauma resuscitation") must be efficient and error-free. During trauma resuscitation, the trauma team identifies and treats potentially life-threatening injuries and develops a plan for subsequent patient care. Many of the initial patient care decisions are made based on the information from the injury scene. EMS crews transporting the patient to a trauma center play a key role in delivering this critical information. However, the handover of medical information from the field is still confined to a mixture of handwritten notes on scrap paper, mental recollection, and verbal reports. Current information transfer is generally inadequate because it lacks structure and continuity, and results in communication failure and missing information. EMS staff rarely receive formal training in conveying critical patient information [22]. In addition, the receiving trauma team members often immediately start with patient assessment and sometimes pay little attention to what is being said during EMS briefings [20]. The EMS crew has no time to generate an extensive report and the trauma team does not have time to either read or listen to it.

We have conducted an observational study to examine current practices in information handover between EMS crews and trauma teams and to gain insights into how technology should be designed to support information transfer in this dynamic and safety-critical environment. We observed how EMS crewmembers conveyed information from the field, what type of information they reported, and what artifacts they used for recording and remembering patient information. We also observed how trauma team members received the reports, what techniques they used to retain and recall information, how useful or important the reported information was later in the resuscitation event, and what type of information they sought from EMS crews after receiving initial reports. For clarity, we use the term "EMS crew"

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to refer to a variety of emergency medical services staff, such as first responders, technicians, paramedics and air-ambulance crew.

In this paper, we focus on information handover in the trauma bay upon patient arrival because this information has direct impact on patient care. Information handover that occurs before patient arrival by radio or cellular link is primarily used for team preparation and is excluded from this analysis.

We begin with a discussion of background and prior work on information handover. We then present an overview of the study methodology. Next, we present the findings from our study, first providing examples that show the problems in current information handover practice and then presenting the results of analysis of EMS reports and trauma teams' questions. Finally, we summarize the results and discuss key challenges for designing technology that supports information handover in this collaborative, high-risk environment.

2. BACKGROUND

During trauma resuscitation, information handover occurs upon patient arrival to the trauma bay when care is being transferred from the EMS crew to the trauma team. Before patient arrival, the EMS crew transporting the patient notifies the trauma center by radio or cellular link. 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 portions of the physical examination). Trauma team members receive notification about an incoming patient by pagers and immediately assemble in the trauma bay. The 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 pre-arrival call is usually received by an emergency department (ED) nurse, who then relates this information to the trauma team members as they assemble in the trauma bay. 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 size of a trauma team can vary based on the time of the day, type of the injury and staffing. The trauma team composition is similar at most academic trauma centers. The core members include a team leader (TL), an attending physician (ATP), a primary nurse (PNR), a nurse recorder (REC), a clinical care technician (CCT), an orthopedic surgeon (ORT), and a surgical resident.

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 the resuscitation on a paper-based trauma flow sheet. Unless called to another duty, the EMS crew stays in the trauma bay briefly to answer questions. Typical trauma resuscitation lasts about 20–30 minutes. The short duration and urgency of the event impose constraints on the forms and extent of information transfer in the trauma bay.

There have been some attempts to introduce structure to information handover in emergencies. The U.S. National Standard Curriculum for training emergency medical technicians lists the essential elements of verbal report and the order in which they should be given [5] (Table 1).

Table 1. The essential elements of an EMS verbal report [5].

(a)	Identify 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

EMS crews usually use the mechanism of injury as the starting point to structure their verbal report and then provide additional details reflecting the structure of the ATLS protocol [1]. The receiving trauma team then uses the ATLS protocol to guide the evaluation and treatment procedures during the subsequent trauma resuscitation.

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. A summary of patient injuries based on a pre-arrival call may also be written on the whiteboard, just outside the trauma bay.

3. RELATED WORK

Efforts to improve clinical handover have been driven by adverse outcomes that have occurred due to the poor quality of information transfers [3]. Much attention has been paid to safety literature and studies of hazardous events in non-health industries with the expectation that practices used in these settings to ensure environmental and workers' safety could be adopted in the healthcare industry. Several studies have investigated hazards in process plants, aviation, and heavy industries, and identified inadequate communication between shifts as a key problem leading to adverse outcomes [7],[10],[13],[14]. These studies have recognized the need for a formal procedure for handover, and recommended open lines of communication to middle and senior management regardless of status, as well as the use of logbooks, documentation and checklists to facilitate accurate information transfer.

There has been substantial research on clinical handover in the medical and human factors domains, but little work has been done to examine information transfer in trauma resuscitation between EMS crews and trauma teams. Studies of clinical handover have mostly focused on intra-professional information transfer, such as nurse-to-nurse handovers during shift change [4],[9],[21] or handovers among physicians [8],[19],[24]. These studies have showed that there are few guidelines specifying what information should be included in patient handover and how it should be transferred. Current handover methods such as face-to-face communication, patient bedside handover, and audiotaped handover were found ineffective and often resulted in communication failure or missing information.

Information handover in trauma resuscitation differs from other clinical handovers in that it occurs under time pressure and is primarily verbal, without the use of media or technology. The few studies that have examined the quality of patient handover by EMS staff in the resuscitation room [17],[20],[22] revealed several problems. Thakore and Morrison [22] found that quality of handovers varied significantly among EMS crews and lacked structure. Additionally, it was found that only a few members of the trauma team paid attention to what was said, resulting in EMS staff's dissatisfaction with the handover process. Scott et al. [17] found that physicians recalled only about 30-40% of verbal information reported by EMS crews. Talbot and Bleetman [20] ran a pilot study to explore whether structured EMS reports result in greater information retention than unstructured ones. Although their findings are inconclusive, they indicate that structuring the handover may not yield clear advantages. These studies have limitations in that they primarily relied on surveys and subjective perceptions of the medical and EMS staff, and rarely used observational data to corroborate the findings.

Several technological interventions have been developed to facilitate clinical information handover. An evaluation study of an electronic handover system for surgical units revealed that freeform text entries were inadequate to convey all the information required for a thorough patient handover [2]. Wilson et al. [23] found that medical staff in their study preferred wall display over verbal handover reports because it helped them to visualize and better memorize patient information. There are several commercially available electronic systems developed to help EMS crews prepare prehospital care documentation, e.g., emsCharts. These systems, however, are rarely used at the scene or during the transport, because EMS crews do not have time for the required data entry. Their main use to date has been for preparing an archival record after the handover [B. Fischberg, personal communication].

Previous studies have focused on the quality of the handover process and not on the subsequent use of the transferred information. An understanding is needed of how and when the transferred information is subsequently used during the resuscitation and what obstacles are encountered. Several factors may be at play. Information may be inadequately reported or it may be adequately reported but forgotten by the time it is needed. The former case would call for technology to standardize the handover to ensure that all relevant information is transferred. The latter case would call for memory aids to help the trauma team recall the reported information. In addition, the EMS crew may report information correctly, but trauma team members may not assimilate it because of being busy with patient evaluation or due to their late arrival to the trauma bay. Technological aids may help ensure that the reported information can be recalled when needed by any team member. Based on this understanding, technological solutions could be designed that reduce the impact of human factors on handover effectiveness and improve patient safety and efficiency. The report ideally should be represented in a structured electronic form, so that it can be easily indexed and customized for different roles of trauma team members.

4. OBSERVATIONAL STUDY

We performed an observational study in a regional Level 1 trauma center to acquire an understanding of the information handover process that takes place between EMS crews and trauma teams. A Level 1 center provides the highest level of trauma expertise and must meet strict national standards for this designation [1]. Over the past two years, we observed about 50 resuscitation events. We videotaped and analyzed 18 resuscitations, because this process is time consuming and the videos were only available for a limited time. In 11 events, the patient was transported by ground, and in the remaining seven events, the patient was transported by air.

4.1 Methodology

Participants: Participants in our study were EMS crews and trauma teams that were involved in 18 handovers. On average, there were four EMS crewmembers in each event. The exact number of trauma team members is difficult to determine because of the dynamic character of the trauma team but we estimate that several dozen health care providers were involved, including physicians, residents, nurses, technicians, anesthesiologists, pharmacists, and medical students. Additionally, we interviewed one EMS educator to gain insight into the EMS training procedures.

Procedure: Two ceiling-mounted cameras and microphones were installed in the trauma bay to record these events. To maintain confidentiality, recordings were transcribed within 96 hours and then erased. Transcripts were produced by a member of the research team who was trained in a one-day didactic trauma resuscitation course. Starting from the moment of patient's arrival to the trauma bay, all discernable actions of EMS crews and trauma team members were transcribed. Each transcript line included the kind of action or utterance, and identified who performed a task or spoke based on their role. The transcripts were then coded using a communication coding scheme that we developed for the purposes of this study. The communication codes included directives, reports, inquiries, responses, clarifications, acknowledgements, and summons. Observational data was collected through note taking. Due to the privacy concerns, we were unable to review information from the patient records for this study.

Data Analysis: EMS reports from 18 resuscitation events were extracted from the transcripts and tabulated to uncover an underlying structure in information handover and the subsequent use of the transferred information. We analyzed information items that were reported by the EMS crew without prompts from the trauma team members. We also studied similarities and differences across the reports.

We then reviewed the transcripts to identify inquires by the trauma team members about prehospital events, posed during and after the handover. We analyzed inquires using an open coding technique to identify the categories of information requested. This analysis provided an insight into trauma teams' knowledge gaps caused by incomplete, missed, or forgotten EMS reports. More specifically, our analysis of inquiries yielded a list of information items that trauma teams needed from EMS crews but were not received due to the poor quality of information handover.

The observational data from personal notes were also analyzed using an open coding technique. This analysis yielded a set of distinct themes that describe the process of information handover in trauma resuscitation.

5. FINDINGS

We first present some general observations that illustrate the process of information handover in the trauma bay. These findings highlight some of the problems encountered during the process.

We then present the findings from our qualitative analysis of initial EMS reports and questions posed to EMS crews during the observed trauma events.

5.1 Observations about Initial EMS Reports

Information handover process lacked structure and followed a question-answering pattern. We observed that initial reporting by EMS crews was usually initiated by a request for a summary of what happened at the accident scene. These requests typically came from the team leader asking "*What did we get?*" or "*What's the story?*" Information transfer was mostly done in a freeform, story-telling manner. The initial reports were short, few-sentence long descriptions of how the patient was injured. The following report is from event #4:

> *"Alright… 20-something years old, he was T-boned at the high rate of speed, they extricated him up from the bottom, very combative... He was driver, struck on the passenger side, we tried to intubate him…"*

We learned from an interview with the EMS educator that EMS crewmembers do not receive an official training on giving verbal reports. The structure of the reports usually emerged as a best practice through experience. The EMS educator described EMS reports as following an "invisible structure," driven by the mechanism of injury and the ATLS protocol. For example, if the patient sustained stab wounds, the report would start with the number and locations of the wounds. This description would be followed by reports of the airway, breathing, circulation and disability injuries and treatments. The reason why this structure is "invisible" is that EMS crews skip information that is "irrelevant" or "non-contributory." For example, if the patient's airway was unobstructed, the report would exclude airway information and move onto breathing. An example of a report that followed this invisible structure is from event #18:

> *"Good evening ladies and gentlemen! This is [patient name], [age] year old Caucasian male, four stab wounds. No history, no meds, no allergies... Sustained four stab wounds: two in the left chest, one left flank, one in the right scapula. Lungs are clear, vital signs have reached about 120 by palp, good radial pulses… you got 16 in the right arm, and he is ready for further evaluation."*

Upon hearing the initial report, the team leader would often ask a few follow-up questions. This practice of question answering, immediately following the EMS report was commonly observed. Table 2 shows an example of the initial report followed by questions posed by the team leader and attending physician.

Information handover occurred at two locations and was sometimes given by more than one EMS crewmember. Upon arrival, the EMS crew gave an initial report to the team members around the patient stretcher. After fielding questions from the trauma team, the EMS crewmember approached the recorder's desk to provide additional details (Figure 1). Only the nurse recorder heard this additional information and entered it in a paper-based trauma flow sheet. Because trauma team members rarely use the flow sheet for real-time information acquisition [16], this process resulted in many repeated questions among the team members. Furthermore, the recorder could not follow and record the evaluation process that had started because of being focused on receiving additional information from the EMS crew.

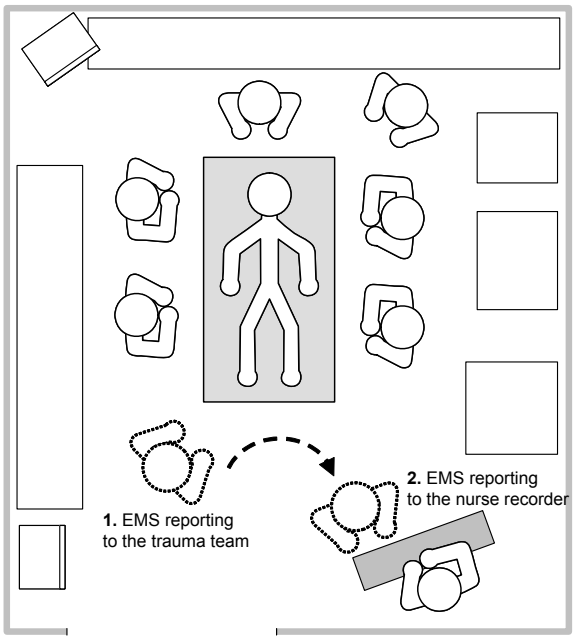

Figure 1. Positions of the EMS crewmember and the trauma team during information handover.

It is important to note that the trauma flow-sheet form is laborious to maintain because all entries are by hand and interpretation is being performed simultaneously with recording. Because of divided attention, the recorder often missed key findings by the team as they started evaluating the patient and had to inquire about these findings later.

We observed in several events that one EMS crewmember started the reporting, but was then interrupted by another crewmember, who took over the reporting. In event #6, we noticed that the team leader posed several questions to one EMS crewmember about the accident details. While he was answering, another EMS crewmember entered the room and started a report, apparently unaware that the first EMS crewmember had already given the report. Simultaneous presentations introduced delays in patient evaluation and confusion about the details of the accident. Another common practice we observed was one EMS crewmember briefing the team and a different one briefing the recorder. An example of parallel reporting comes from event #17 (Table 2). Upon arrival, one EMS crewmember (EMS4) started briefing the recorder, while another one (EMS1) started briefing the team members gathered around the patient stretcher.

Artifacts used during information handover were mostly limited to handwritten notes. Information handover in trauma resuscitation is verbal and primarily relies on mental recall by the EMS crewmembers. We observed them using notes that were handwritten on a scrap of paper to recall information from the field. This 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). In two events, we observed EMS crewmembers showing the nurse recorder images of the accident scene taken by their mobile phones. The EMS crews used portable devices for monitoring the patient vital signs during the transport, with the capability of storing the vital-sign time series and detecting anomalous events in those time-series. This "time journal" can be transmitted

Table 2. Excerpt of the initial EMS reporting upon the patient arrival to trauma bay in Event #17 (some lines are omitted).

Line #	Time	ACTOR	ACTION	SUBJECT	COMMUNICATION
9	0′	EMS1, EMS2, EMS3	((bring in the patient, who is intubated, has oxygen mask on his face, cervical collar, and decompressed left chest))		
11		EMS4	((enters room, approaches	REC))	... (starts reporting about the patient and accident)
12			((lots of noise and people around REC's table, also around patient as they prepare for transfer))		
14	0′23″	EMS1	((does manual ventilation, talks to	TEAM))	Alright, the first thing you're gonna notice is that he's not on a backboard…
15		TL	((talks to	EMS1))	Yeah...
17		EMS1	((talks to	TEAM))	Yeah, well, that's cause he was fighting and fighting and fighting and we had to get him off the (?) somehow and that would be the only way.
18	0′33″	EMS1	((continues report, talks to	TEAM))	He was fighting, he wasn't allowing us to do anything, not even putting an IV...
19		TL	((talks to	TEAM))	Can we get the slider!
27		EMS1	((talks to	TEAM))	Anyway, severe damages to the interior of the vehicle, blood all over the airbag, dashboard (?)...
28		EMS3	(enters room carrying backboard)		
30		EMS1	((continues report, talks to	TEAM))	He was tachycardic, complaining of chest pain on his left side, he has extremely diminished breath sounds, pulse ox very low, was narrow at the point...
31	0′54″	TL	((puts stethoscope, talks to	EMS1))	What is it now?
32		EMS1	((talks to	TL))	Pulse ox is 100%, (?) is 40, and we had to intubate him because he wasn't getting any better, he was very hypoxic.
33		TL	((talks to	EMS1))	Okay.
36	1′8″	EMS1	((continues report, talks to	TEAM))	We gave him total of 10 of versed, 20 of etomidate, 100 of succs
42	1′34″	EMS4	((at the REC's desk, talks to	CHF))	(gives lots of details from the accident, hard to hear exactly what's he saying)
77	3′30″	ATP	((talks to	TL))	Why was he intubated? He wasn't...
78		TL	((talks to	ATP))	He wasn't breathing in the field...
79		EMS3	((talks to	TL))	Who said he wasn't breathing in the field?
80		TL	((talks to	EMS3))	Well, he was breathing but…
81		ATP	((talks to	EMS3))	He got intubated why?
82		EMS3	((talks to	ATP))	He got intubated because he was very hypoxic... Became cyanotic...
86	3′37″	EMS3	((yells across stretcher, talking to	ATP))	He... ah... Decompressed the chest
89		EMS3	((moves to other side of stretcher, closer to ATP, continues talking to	ATP))	(explains decompression and intubation, also mentions meds administered)

wirelessly to hospital computers, but we never observed them using this feature during handovers. The EMS educator explained that the wireless transmission was not convenient and EMS crews believed that verbal reports were sufficient to convey important information about the vital-sign time series. In addition, the EMS crews had access to rugged portable PCs loaded with the emsCharts software for archival documentation purposes, but these were not used during handovers.

Difficulties in information handover were worsened when the reports were given second hand, with a minimal input from EMS crews. This problem usually happened when the patient arrived by air. Because the initial report was given at the helipad to the present team members, the EMS crewmembers rarely repeated the full report in the trauma bay. The team leader or a nurse usually gave reports in these cases. The team leader sometimes missed the initial report at the helipad and then asked those who heard it to retell the report. Meanwhile, EMS crews only helped transfer the patient from their stretcher to the trauma bay gurney. In this way, secondary sources of data were used even when primary sources were available.

Information handover occurred simultaneously with patient handover. Reporting was mostly done in parallel with patient transfer from stretcher to gurney. This practice caused difficulties in information transfer because of teams' divided attention and interruptions in reporting. The team was focused on transferring the patient and paid little attention to what was said in the reports, resulting in questions about items that had already been reported. In events #11, 13, 14, and 16, however, the teams first listened to the EMS report and then initiated patient transfer. While it is difficult to conclude that this strategy was more effective based on only four events, it is intuitive that the lack of interruptions achieved with this practice is beneficial.

Trauma teams rarely probed the decisions about diagnoses and treatments made by EMS crews at the scene or during transport. The information conveyed by the EMS providers was important for the evaluation and treatment and often was used immediately by the trauma team. However, trauma teams rarely questioned decisions made in the field. Prior work has shown that the purpose of information handover goes beyond a simple transfer from outgoing to incoming staff members [14]. During an information handover, a person who is accepting responsibility and authority has a fresh perspective and is thus capable of detecting fixation or omission errors [15]. This behavior is manifested through asking probing questions that serve to detect errors. For example, a

person taking over responsibility may follow up on a reported item by asking: "*Do you know this for sure?*"

In event #17, we observed that the trauma team decisions were determined by the EMS report. The EMS crew reported that they had decompressed the left chest because of patient's complaints about pain on the left side (Table 2). When the patient's vital signs indicated breathing problems, the team leader concluded that this was due to internal bleeding in the left chest and decided to drain the blood by inserting a chest tube. The team leader did not ask the EMS whether their treatment had any effect during the transport. It appears that it did not, because the patient continued to be combative, and the EMS crewmembers had to sedate him. Later in the event, x-rays showed that the patient had bled into the right chest and the team inserted a second chest tube in this side. Valuable time had been lost and the first chest-tube insertion might have been avoided with additional questions of the initial EMS report.

We observed in event #17 only one question probing EMS crew's decisions, i.e., when the attending physician asked why they intubated the patient (Table 2, line 77). However, the team did not question EMS crew's decision to decompress the left chest and whether it had any effect. It appears that the problem in event #17 was that EMS crewmembers did not report a full description of their treatment and the facts on which their decision to perform the procedure was based. Instead of asking for clarification of the EMS-crew's decision making, the trauma team appeared to draw their own conclusions about the EMS crew's decision. This tendency was observed in all 18 events. Due to the urgent need to start with patient evaluation, trauma teams usually skipped probing questions.

5.2 Initial EMS Reports

In this section, we present the findings from our qualitative analysis of initial EMS reports. EMS reports include a great deal of information, which can sometimes overwhelm the team. Not all of this information is needed immediately, and some of it only becomes useful later during the resuscitation. The types of information provided in EMS reports are shown in Table 3, and are organized into five high-level categories. Below, we discuss each category along with our observations of how much the reported information mattered to the team and whether or not it was used in resuscitation.

Demographics: We observed that the reports typically started with demographic information when available. In case this information was not available, the EMS crewmember would explicitly state that it was missing, as in event #8:

> *"Alright, I have unknown age, unknown name, male, older, the driver of a motor vehicle, the dump truck which rolled over…"*

Age and gender were reported in 15 out of 18 events. In the remaining three events, two cases arrived by air and reports were given by trauma team members who failed to include these data in their reports. In the last event, the EMS crew forgot to report any demographic information because they were distracted by a difficult patient transfer. Information about patient age is important to trauma team members to give them perspective about the impact of observed injuries and the type and effectiveness of treatments given.

Table 3. Categories of information provided during handover.

Demographics	• age • gender • medical history/allergies	• name • date of birth (DOB)
Mechanism of Injury	• type • details - driver / passenger	- restrained / unrestrained - vehicle specs - number & locations of wounds
Injuries (sustained or suspected)	• deformities • lacerations • bruises	• abrasions • patient complaints
Physical findings and vital signs (observations and monitoring)	• airway in transport • breath sounds • vitals - at scene - en route - EKG rhythm chart • symptoms	• neurological - alertness and orientation (A&O score) - patient memory - loss of consciousness (LOC) • alcohol on board • lab tests - glucose test • positive findings
Treatments given	• IV access (vascular access points) • fluid • treatments en route - type - details (time, quantity, frequency, …)	• medications en route

The patient name was initially reported in eight out of 18 events. In another seven events, it was reported upon request from the trauma team. Patient name was not included in the report in three events; it was provided later upon request from the hospital clerk responsible for administrative paperwork. The patient name was important to trauma teams for several reasons. If a patient was conscious, the team members used it to address the patient directly by name, to further assess their mental status. We also observed patient name being used for retrieving x-ray images later in the event, for labeling blood samples, and for labeling the notes and charts that were used in the process.

Exact date of birth was provided in four events only. It was never included in the initial EMS report, but requested later by either the recorder or hospital clerk. It appears that this information had administrative importance only.

The patient's medical history, including allergies, current medications and prior hospitalizations, were also part of the initial reporting. If this information was not conveyed in the EMS report, it was requested later in the resuscitation. The nurse recorder usually requested this information at the start of the evaluation and recorded this information in the flow sheet. Physicians, however, needed a patient's medical history only at the time they prescribed new medications. Availability of this information depended on whether the patient was conscious or unconscious at the time the EMS crew arrived at the accident scene. Patient medical history at times was observed to have a role in selecting treatments. We observed that even when this information was reported during the handover, the team leader asked for it either from the patient or from other team members. While team leaders may have forgotten this information, they also might be using repeated inquiries to confirm the information. The patient under stress may answer the same question differently at different times, or may forget to mention important facts. Also, the team leader might be using these questions to assess the patient for brain injury. Therefore, subsequent questions about patient medical

Table 4. 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

history may still occur even if this information is always included as part of the initial report.

Mechanism of injury: An accurate account of the mechanism is critical for trauma teams because it enables them to anticipate specific injuries or injury patterns. Examples of the mechanism of injury include motor vehicle accident, motorcycle crash, fall, stabbing or gunshot wound. We observed this information being reported in all 18 events. As mentioned, the mechanism of injury helped in "structuring" the EMS report. The EMS crewmember would first state the mechanism of injury and then provide more details. In case of a motor vehicle crash, the report also included whether or not the patient was the driver or passenger, whether the patient was wearing a seat belt and other details about the incident. In the case of stabbing, the report included the number of wounds and their locations.

Injuries (sustained or suspected): If the patient had visible injuries, such as abrasions, fractures, or lacerations, this information was included in the EMS report. Patient complaints were reported in eight events and were requested in one event. Information about patient complaints is important to the trauma team because it can be a sign of an internal injury that is not easy to detect by external inspection. We observed the team leader asking conscious patients questions such as "*What hurts?*" or "*Where do you feel the pain?*" even after being briefed about the patient complaints in the EMS report. Whether or not this information was included in the report, injuries were repeatedly assessed and reported throughout the event as the team conducted the evaluation.

Physical findings and vital signs (observation and monitoring): The most common information types reported in this category included alertness and orientation score (nine events), vital signs en route (eight events), vital signs at scene (six events) and loss of consciousness (five events). Assessment of the patient's alertness and orientation (A&O) provides a rapid method for detecting major neurological injury. When the reported A&O score was high, the team usually did not inquire further about patient neurological status. Vital signs at scene and en route are important because these data convey the initial patient status and any changes during the transportation. Finally, loss of consciousness was always reported for patients who were either found unconscious or lost their consciousness en route. Even for the patients who arrived conscious, the team inquired about their consciousness state during the transport.

Table 5. Questions among trauma team members about prehospital 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

We observed that a description of the airway status was skipped if it was unobstructed. Information about airway was also implied through EMS reporting about treatments, such as endotracheal intubation. Information about breath sounds was reported in five events and skipped in remaining 13 events. Regardless of whether or not this information was reported by the EMS crew, the team always checked patient's airway and breath sounds upon arrival.

Treatments given: Information about treatments provided en route was regularly reported. This information signaled immediately what was wrong with the patient. The EMS crew typically reported the number of vascular access points, the size of the intravenous catheters (IV access), and if any fluid or medications were given. If this information was not initially reported, the team would request it. For complex treatments such as intubation, the team sometimes asked probing questions. It is important for the team to know why the patient was intubated and what medications were given at the time of intubation. As already described, we observed few probing questions about EMS crews' decisions.

5.3 Questions during Handover and Resuscitation

In this section, we present the findings from our qualitative analysis of questions about prehospital care that were asked during and after the handover. The key categories that emerged from the analysis of questions posed to EMS crewmembers are shown in Table 4, while categories of questions asked among the trauma team members are shown in Table 5. Analysis of questions provided an insight into 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), we can learn where the gaps in information needs are and when they occur. This analysis in turn can help guide the design of technology for facilitating information transfer in the trauma bay.

The trauma teams asked the EMS crews 77 questions in 18 resuscitations (4.3 ± 2.8 questions per event [mean ± SD]). Additionally, there were 58 questions about prehospital care among the trauma team members after EMS crews left (3.2 ± 2.6 questions per event). Given the 13 information types typically reported by EMS (excluding event summary) in Table 4, the relatively high overall number of questions (7.5 ± 5.4 questions per event) indicates incomplete handovers and low retention of information. The lack of some items in Table 5 and different relative frequencies compared to Table 4 reflect the changing

information needs of trauma teams as resuscitations are progressing.

It is also interesting that questions about prehospital 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 prehospital care information. In other words, every fifth question was about prehospital 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 event, the patient suffered a fall and team members' inquired about whether the patient jumped or slipped and from what height. In four out of 18 events, 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 events 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, we often observed EMS crews 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 crews left the trauma bay (Table 5) 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.

In conclusion, questions asked during or immediately after information handover while the EMS crews were still present were mostly to clarify the story provided by the EMS crewmembers. On the other hand, questions asked among the trauma team members after EMS crews left indicated gaps in teams' knowledge and information needs. These gaps occurred either because EMS crews 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.

5.4 Summary of Findings

The above findings describe the current practice of information handover observed in a regional trauma center. We observed that EMS reports were incomplete, unstructured, and lacked continuity. Although EMS crews knew all the information most of the time (they rarely failed to answer questions from trauma teams), it appears that due to the time pressure and interruptions they often failed to follow a particular structure and failed to report important information.

The problem, however, is not only in the reports given by EMS crews but also in the assimilation of the reports by the trauma team. Information transfer in trauma care is frequently done simultaneously with urgent medical treatment, and providing this treatment takes priority over a complete understanding of what has happened to the patient before arrival at the hospital. Some trauma team members were focused on patient evaluation while the report was given, so they only paid attention to the items they needed to know immediately. Additionally, trauma team members sometimes missed the report entirely because they arrived late. The team had difficulty maintaining group knowledge, because staff was entering and leaving the room to obtain missing equipment or to attend to other trauma patients in the emergency department.

We did not observe any information reported by EMS crews that was clearly not useful for trauma teams during resuscitation. Positive findings about patient state, such as "*pelvis is intact*" or "*no neck, back, or any other complaints*," were occasionally reported (four instances across 18 events) and appeared not to affect the subsequent resuscitation. Failures in information transfer can negatively affect patient evaluation and outcome. We believe that technology can facilitate information transfer and alleviate some of these problems.

Within the broader context of the work of EMS crews and trauma teams, we identified key issues to consider for technology design. First, EMS crews gather prehospital information for two purposes: reporting to trauma teams during patient handover and for archival documentation. Systems designed for documentation of trauma events require extensive clerical data entry, much of it not needed for patient handover, and hence are not suitable for preparing handover information. The EMS crews need a system specifically designed for entering only the information that will be needed by the trauma team. Our study revealed which information items are required by trauma teams. The information prepared by EMS crews for patient handover could be stored in a database and used later on by a different system for archival reporting. In this way, EMS crews would need to enter only additional information that was not entered for information handover, thus avoiding duplicate clerical data entry.

Second, different participants in information handover have conflicting needs. On the one hand, EMS crews would prefer to efficiently transfer information at the time of patient handover and move on to another duty. On the other hand, trauma team members may rather not receive all information at once because it is not convenient to memorize and recall these data later. Trauma teams would like to receive the information when they need it at times distributed over the resuscitation. Moreover, trauma team members with different roles need different information items at different times. This finding is the key reason for inquiries during resuscitation about the information that was already reported during patient handover.

6. CHALLENGES FOR TECHNOLOGY DESIGN FOR TRAUMA INFORMATION HANDOVER

Our findings indicate that a feasible solution must address the needs of both EMS crews and trauma teams in the context of their work. Existing commercial solutions for EMS reporting and documentation, such as emsCharts (www.emscharts.com) and Safe Triage (www.safesurgerysystems.com), focus either on archival documentation for EMS or on efficient recording and information handover, but none addresses the subsequent use of

the transferred information by the trauma team. The specific challenges for technology design that emerged from our study are:

Report preparation: The challenge is to minimize the effort by EMS crews to electronically record the information that is essential for the trauma team. The effort in using the interface for report preparation should be as close as possible to that of preparing handwritten notes. Our study identified what information is used by trauma teams during resuscitation. These findings can guide the interface design for report preparation.

Report structure: Structured reporting and data storage can compensate for frequent changes in team membership and the constant intrusion of other high-priority needs that cause information to be overlooked. The challenge in structuring the report is in deciding what information should be included in the handover report, and in organizing and prioritizing the display. Our study provided insights into what information is used by the trauma team and at what time it is needed. Structured reports may help improve handover efficiency but will not solve the problem of memorizing information for later use in the resuscitation.

Report timing: Because of the urgent need for trauma team to start with patient evaluation, the challenge is to maintain the team's attention while respecting the urgency of the situation. Initial EMS reports currently include items that are important but not needed immediately for patient evaluation. An alternative is to stagger the reporting throughout the resuscitation. The EMS crew could initially give a partial report, including only the information needed to start the evaluation. The remaining information would be transferred to a trauma-bay computer and could be looked-up when needed, without the need for the EMS crew to remain present during the resuscitation.

Report retention: Trauma team members often lacked information they needed at later points in the resuscitation because they missed the initial report, were distracted when the report was given, or simply were not able to recall the information. The challenge is to make report information available to trauma team members throughout the resuscitation. Staggered reporting also could address this challenge because the information is retained in computer memory.

Re-reporting completeness: When patient arrives by air, the challenge is to make the full EMS report given to a few team members at helipad available to other team members in the trauma bay. In these cases, the prehospital information is retold by a trauma team member, who has only second-hand knowledge of the situation. Again, having the full report available electronically during the resuscitation could also address this challenge.

Report probing: Because the trauma team is under time pressure, they may skip probing critical pieces of information, such as en route diagnoses, treatments and patient's reactions, that they otherwise may wish to know more about. If non-urgent information is electronically transferred for later use, more time can be allowed for probing EMS crew's decisions. The computer system may also prompt these kinds of questions when such critical information is entered into or retrieved from the EMS report.

6.1 Checklist as a Potential Solution

Checklists are a simple method for improving team performance when routine tasks can be identified [6],[15]. For example, a checklist for verifying the safety 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 [25].

Systems such as emsCharts and Safe Triage already use electronic forms that include checklists. Safe Triage additionally allows marking external injuries (lacerations, abrasions, wounds, etc.) on a graphical representation of human body. An improved solution can be based on existing technologies, but redesigned to address the challenges identified above. A redesigned electronic checklist should allow EMS crews at the accident scene and during the transport to enter rapidly information that is essential for the trauma team. The benefit of a checklist is that it reminds the EMS crew of what is needed and limits their effort to collecting essential information only.

Our findings set the framework for structuring the checklist for preparing prehospital information for handover. The analysis of reports and questions yielded the types of information that were reported and then either used or not used during trauma resuscitation. This list of information items and their importance and timing can help us determine and prioritize the items of the checklist that could be used for information handover in trauma bay. If the checklist is not reasonably sized, it will likely not be useful. Because of the time pressure, the EMS crew will not invest work required to complete it and the trauma team will be interested only in the information they need for resuscitation.

Checklist-based reporting implies providing information in the exact same order every time. An example is a checklist used in airplane cockpits where pilots and co-pilots always follow the exact order of items on the checklist when preparing for a flight. This approach may not be adequate for trauma teams because trauma team members need different information at different times, and the timing is mostly unpredictable due to variations in the resuscitation process. Each resuscitation tends to need the same pieces of information, but not always in the same order.

Our observations imply that there is no need to display the entire checklist at once. Trauma teams would not be able to absorb a long list of information items due to the time pressure. In addition, this approach could potentially cause information overload. We believe that careful consideration should be given to the design for information access and visualization. Some prehospital information could be displayed by default on wall displays, while other information could be available on demand. The initial report delivery by EMS crews can be augmented by wall display of the currently relevant information. Structured data display would simplify both entering and finding the needed information.

7. CONCLUSIONS

We have conducted an observational study in a regional trauma center to examine the characteristics of information handover between EMS crews and trauma team members during trauma resuscitation. Although based almost entirely on observational data, the study revealed key problems that occur during information handover between the two teams. The results of our study showed that prehospital reports were often incomplete and were followed by many questions from trauma teams. EMS crewmembers mostly relied on mental recall while providing verbal reports, which was occasionally accompanied by handwritten notes to retain specific information from the field. Available EMS electronic systems were found impractical for initial reports because they required lengthy data entry.

We also examined subsequent use of reported information during resuscitation events. We found that trauma teams faced significant challenges in retaining reported information. EMS reports included many categories of information, some of which was not immediately needed. Trauma teams mostly remembered information they needed for immediate patient care and inquired about other information later in the process.

We have identified a set of challenges faced by both EMS crews and trauma teams during information handover. Similar challenges arise in other domains that involve information transfer under time pressure and stress, e.g., EMS dispatch, nuclear power plants, or traffic control rooms. We believe that our findings can be used to inform the design of information technology to support information handover in time- and safety-critical domains.

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