THE ART OF SAVING LIFE:
interaction of the initial trauma care system from a cognitive science perspective

Gro Dahlbom

Department of Computer and Information Science
Linköping University

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Supervisor at Linköping University: Nils Dahlbäck
Supervisors at Sectra: Joackim Pennerup, Claes Lundström

Department of Computer and Information Science
Linköping University
Abstract

Trauma care is the treatment of patients with injuries caused by external forces, for instance car crashes, assaults or fall accidents. These urgent patients typically arrive at the hospital’s Emergency Department, where they are treated by an interdisciplinary team of physicians and nurses, who collaborate to identify and address life-threatening injuries.

In this thesis, the urgent phase of trauma care has been explored through observations of trauma calls and interviews with trauma care professionals, with the purpose of mapping the workflow and providing a basis for a discussion of IT systems within trauma radiology. The professionals, procedures and tools involved are collectively described as the initial trauma care system. There has been a focus on interaction between the units of this system, as well as on how decisions regarding treatment are made, often with the help of medical imaging.

The initial trauma care system functions under significant time pressure, striving towards the well-defined objective of saving the life of the patient. To a great extent the system relies on standardized procedures, aiming for screening life-threatening injuries. The trauma team features a clear hierarchy and distinct roles, where the team leader role is considered vital for the team’s performance. Experience is valued and important for everyone, especially since the team often makes decisions, that may affect the future of the patient, based on incomplete information about the situation. Therefore, CT (computed tomography) images offer valuable decision-making support.

The respondents are fairly satisfied with the current tools for viewing and manipulating radiological images. Little support for the need of improved or novel IT systems in trauma radiology is found, as is the use for 3D visualization of radiological images in this domain. Informants recognize communication failures and lacking teamwork as the major problems in trauma care. Difficulties like this may be decreased by education and training regarding these issues.
Acknowledgements

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Introduction

In this chapter, the reader will be introduced to trauma care and the premises of the thesis.

Trauma care – the treatment of the injured

“Traumatic injury is the leading cause of death in the first four decades of life in the western world” (Cole & Crichton, 2006, p. 12)

Trauma is, in medical context, basically a physical injury caused by an external force (Martin & Meredith, 2008). A trauma patient is thus an injured patient, as opposed to a patient with an illness. If the patient has experienced great mechanical violence, penetrating violence against head/thorax/abdomen, and/or simply is in a life-threatening state, we talk about a major trauma and a severely injured patient in very urgent need of care (R20). Multi-trauma implies that the patient has a combination of several injuries, which is often the case for the major trauma patient.

Trauma is one of the most common causes of death in Sweden for persons under 44 years of age. About 4500 people die annually of injuries and substantially more are disabled. Those are frequently relatively young, the average age of patients with major trauma being below 30 years old. Due to the intensity, complexity and urgency of trauma cases, care is very expensive. The overall economic impact of injuries in Sweden is estimated to be 4% of the GNP (Lennquist, 2007).

The causes of trauma vary, but among the most common are motor vehicle accidents, falls and inter-human violence. As a rule, trauma patients arrive by ambulance to the emergency department of the hospital, however, the care starts once the health professionals arrive at the scene of the accident. Adequate decisions and actions by the professionals are crucial for the survival of the patient in all stages of the care, from the on-site work, to transportation, to intensive care, and finally on to rehabilitation. Approximately 30% of trauma related deaths occur between a few minutes and the initial hours after the incident, and improvements in the speed and accuracy of trauma care will reduce these deaths (King & Wherry, 2010).

Once in the hospital, the patient with major trauma is cared for by a trauma team, consisting of several doctors and nurses with different specialties. During the work with the patient, other specialists are usually consulted as well. There are 35 trauma centers in Sweden (Nyström, 2011). The trauma care, however, is carried out somewhat differently amongst these hospitals. For instance, smaller hospitals do not always have a specialized trauma team in stand-by or a fully prepared operating room. Also, Swedish trauma care differs from the counterparts in more densely populated regions, such as Central Europe or the US, being less centralized and not as highly staffed (Lennquist, 2007).
Purpose of thesis and research questions

The purpose of this master thesis is to provide a basis for a discussion about the possible advantages of and needs for implementing new IT solutions in trauma care, especially within the radiological workflow. The aim of the research has thus been to analyze and map the workflow of trauma care. A system perspective has been used, where there has been a focus on the interaction of the professionals within trauma care. There has also been a focus on diagnosis and decision making.

This thesis will answer the following research questions:

- How can the organization providing trauma care be described as a system?
- What are the objectives of this system and how are they achieved?
- How can the collaboration, communication and general interaction between the professionals in the trauma care system be described?
- How are strategic decisions being made within the trauma care system?
- What problems can be detected within the trauma care system?
- What are the needs and premises for new IT systems in within the radiology workflow of trauma care?

Delimitations of the scope

Doctors and their tasks have been the primary focus, rather than the other health care providers involved. The scope of the study has also been limited to the urgent phase of the treatment, i.e. the first hours after the patient arrives at the hospital.

This research has been carried out solely in Swedish trauma centers. There are two reasons for this: First, the pre-study – which the reader can learn more about in the Research method and procedure chapter – indicated that the core of trauma care is quite uniform in most western countries. Second, a thorough but geographically limited study was preferred over a more superficial but broad one, in order to improve the external validity of the research.

Disposition – a reader’s guide

To facilitate the reading of this thesis, the structure is as follows.

Introduction. This chapter. A brief introduction to trauma care, the domain of the thesis, is given. Additionally, the premises for the thesis is presented: purpose, research questions and limitations.

Theoretical framework. Here, the cognitive scientific framework that the study has been carried out within is described. The common denominator for the theories is the notion of “cognition in the wild”, which both functions as a way to motivate the research strategy and forms the analysis. In order to fully understand the analysis it is recommended to read this chapter.
**Introduction to medical imaging.** Since there is a special interest in radiology within this thesis, the fundamentals of medical imaging techniques used in the initial trauma care, together with the current software for viewing and handling image data, can be found here.

**Research method and procedure.** This chapter presents information on how the research has been carried out.

**The standard procedure of the initial trauma care system.** This chapter constitutes the main body of results from the field work, forming a basis for everything that follows. The general workflow of initial trauma care is described – from when the patient arrives to the trauma room until the CT examination is completed - as well as the composition of the trauma team and variations that occur.

**Analysis.** Here, the results of the field work are being reviewed in more detail and analyzed according to the focus of interaction and the integrated system view that is presented in the theoretical framework. Characteristics of the initial trauma care system are also being detected. Finally, difficulties in trauma care that has emerged during the observations and interviews are summarized.

**Recommendations.** In this chapter a discussion of how these problems can be addressed is initiated. What IT systems could provide to the trauma context is also discussed.

**Brief notes on method issues and further research**, chapter 11 – **Conclusions.** Sums up and concludes the thesis.

All quotations from respondents in this thesis has been translated from Swedish to English by the author. If no other reference is given, the source is the ethnographic data. All photographs are by the author, if nothing else is specified.
Theoretical framework: cognition in the wild

The purpose of this chapter is to describe the framework of a certain direction of cognitive science within which this research has been carried out. It justifies the choice of method and influences the results by forming the subjective view of the researcher.

Traditionally, cognition has been seen as a set of information processes that takes place inside the skull of an individual, and therefore was best studied in carefully controlled laboratory experiments, where a person's performance in well-defined, artificial situations could be observed and measured. The prevailing metaphor for the human cognition has previously been the computer – the human seen as an information-processing system; perceiving data as representations, manipulating these symbols according to a set of rules, and presenting output (Hollnagel & Woods, 2005; Hutchins, 1995a).

In modern cognitive science the view is different, and this chapter will review some instances of this. First, a more general framework of cognition as a collection of distributed processes is presented. Second, an application of this view within systems theory is described. Finally, an overview of the concept of tools within these fields is found.

Distributed cognition

“A process is not cognitive simply because it happens in a brain, nor is a process noncognitive simply because it happens in the interaction among many brains” (Hollan, Hutchins & Kirsch, 2001).

Distributed cognition is not a certain form of cognition, like the phrase might lead one to believe, but rather a framework within which to view all cognitive processes. It is a branch of cognitive science claiming that cognition does not only take place in the mind of an individual, it rather occurs and transforms in the interplay of people, tools and the environment. Cognitive processes - e.g. memory, decision making, planning, problem solving and reasoning - may be distributed across the members of a social group, involve coordination with material and environmental structure, and can be distributed through time, so that products of earlier events can influence the subsequent events (Hutchins, 1995a). For example, when a group of people is solving a problem together, discussing and interpreting it, the cognition and flow of information involved is formed by social organizations as well as collective and distributed across individuals (and any tools they might be using) (Hollan et al., 2001). Cultural context also influences the way we think - in any situation there are certain rules, norms and conventions regarding ways to perform a given task, so our cognition can be said to be shaped by the local and global culture (ibid.).

Since we are creatures with bodies forever locking us into relations with our physical environment, our thinking is highly embodied as well, and we are frequently using context to lighten our internal cognitive load. For instance, as I write this thesis, I am constantly externalizing cognition. While jotting down notes I am externalizing my memory; by sorting post-its and making mind maps I literally organize and manipulate my knowledge in space;
writing to-do-lists and timetables is an externalization of planning; and writing pros and cons on separate sides of a line aids in my decision making. There is no way I could compose this thesis solely inside my head.

There are many examples of the cognitive coordination between external and internal structures in the literature as well. In *How a Cockpit Remembers Its Speeds* (Hutchins, 1995b) it is described how airline pilots use perceptual strategies and interpret the spatial location of a needle in the circular speed dial to get a notion of the speed, rather than read the speed as number. In *The Intelligent Use of Space* (Kirsh, 1995) it is showed how people make use of the environment for heuristic cues, such as covering hot handles with kettle-holders so as to remember not to touch them. There are strategies for manipulating external properties to simplify choice, perception and internal computation. Prison, Lützhöft and Porathe (2009) has an ongoing research project, exploring what is called Ship Sense. This is the notion that body related input such as acceleration and balance can be almost as important as visual information when maneuvering a ship, providing a “gut feel” for how the ship is behaving.

The framework of distributed cognition does not criticize the notion that humans are symbol manipulating creatures per se, but strongly suggests that the unit of analysis should be raised from the isolated brain to a larger cognitive system involving context, if any results of applicability are to be achieved. From this follows that cognition must be studied “in the wild” if we are to learn about how people actually perform tasks, i.e. to use ethnographic methods and field studies instead of traditional controlled experiments in artificial environments (Hutchins, 1995a). This concept is applicable to this thesis.

**Joint cognitive systems and cognitive systems engineering**

“In a single term, the agenda of CSE is how can we design joint cognitive systems so they can effectively control the situations where they have to function.” (Hollnagel & Woods, 2005, p 24).

Socio-technical systems are becoming increasingly more and more complex, rapidly changing the nature of work in myriad areas and situations. Until recently, these systems’ support of human work has been neglected, and there has been a lack of understanding of their complexity, in both a theoretical and practical sense, which over the last 25 years led to the development of the discipline of Cognitive Systems Engineering, henceforth abbreviated to CSE. (Militello, Dominguez, Lintern & Klein, 2009; Hollnagel & Woods, 2005) Erik Hollnagel is one of the leading figures within this discipline, and all claims below in this section can be traced to his and David D. Woods book *Joint Cognitive Systems* (2005).

CSE is strongly related to Human Factors Engineering. Both disciplines focus on an appropriate and informed design of products, processes, systems, and work environments, carried out with safety and support of the work of the human(s) using them and being parts of them in mind. Within CSE, however, there is an emphasis on the importance of seeing the
system as a whole, where every component and every action is strongly intertwined with the rest, and where agents and environments are dynamically coupled. The system emerges in the interaction the units of which it consists, and is therefore different to the sum of its parts.

A key concept in CSE is Joint Cognitive Systems (JCS), formally defined as a junction of at least one cognitive system and another cognitive system or an artifact, where a cognitive system is a human being. In more casual terms a JCS can be referred to as any system consisting of people, tools and social constructs (see figure 1). This term stresses the necessity of focusing on the performance of the system, rather than the internal processes of the humans and machines that are a part of it. Physical separateness of units does not necessarily imply functional separateness. CSE also postulates that the notion of “human error” is insignificant – when analyzing risk and accidents, one should look for the flaws in the system that allow failure to occur, rather than blaming a single unit.

CSE also highly corresponds to the distributed cognition approach discussed above, in that context is considered crucial. Systems are embedded in a social environment that provides both limits and resources, and almost all activity is aided by something or someone beyond the singular unit.

Control in the JCS
The concept of control is essential to CSE, as it is a prerequisite for an efficient and effective system. Control is in this context defined as the ability to obtain a desired outcome and cancel or neutralize possible disturbances and disruptive influences. To do this, it is of course necessary to formulate an objective for the process in question.
Control can be described as a continuous loop, as is shown in the COCOM, Contextual Control Model (see figure 2) of CSE. The controller/controlling system has a construct of the present situation. Depending on how this construct relates to the desired state, the controller chooses an action, or a set of actions. The possible actions are denoted as the competence of the system. When these actions are carried out, the state of the system is affected. External disturbances might also influence this state. The controller interprets these events, from them deriving a new construct of the situation, i.e., feedback is obtained and used. And so the loop goes round and round, while striving to obtain a goal or sub goal of the process. The controller may also take a shortcut by skipping the time-consuming feedback step, and instead rely on experience and planning, forming the construct by predicting the results of the actions. This is called feedforward and is used to reduce demands when time is in short supply, or if the system changes so rapidly that the conditions at the end of the analysis/interpretation are different from when it started. However, if the system is to safely rely on feedforward, the controller must have a good representation of how the process to be controlled behaves and develops.

So, control requires the ability to compensate for differences between the actual state and the desired state, and in turn the ability to perceive and notice these differences. Finally, it is also necessary to interpret those differences correctly. On a basic level this could be a device measuring something that is exceeding a certain threshold; on a more holistic system level there are a multitude of variables to consider, which instantly makes the notion of control
more complex. On this level, it is always a cognitive system controlling the JCS, i.e. it has a human element. Since cognitive systems rather seek and select information than passively receive all available data, the construct of the present situation can be biased or lacking, which in turn decreases the level of control. A common problem is information overload, where the cognitive system responds by using various coping strategies, e.g. queuing or filtering information. This enables the system to continue the process but reduces the control precision.

When studying the trauma teams and their workflow, a joint cognitive systems perspective has been used. The focus has been on the functions of the system as a whole, rather than a description of single units. This perspective has thus affected the analysis in large, but in addition to this a section where the initial trauma work is described according to concepts and interests stemming from the CSE theory can be found in the analysis chapter.

**Artifacts – the understanding of tools**

The word artifact can be an ambiguously interpreted. Within radiology it denotes some sort of disturbance in the image, caused by for example movement or the patient’s garments. In this thesis, however, artifact refers to something that is created by humans for a specific purpose, and is thus synonymous to a tool. Artifacts is an important concept in both CSE and distributed cognition, since there is such an emphasis on context and the impact of the environment within those fields. However, there are slight variations between the concepts of their respective approaches as well.

Norman (1993) devotes the better part of his book *Things that make us smart: defending human attributes in the age of the machine* to artifacts and our complex interaction with them. He describes how people constantly use the external world – sounds, gestures, symbols and objects – to represent other things, thereby enhancing their own cognitive abilities. This can be anything from counting on your fingers or using a map, to describing an event with gestures and available objects. These things Norman (ibid.) denotes as cognitive artifacts, and they can be both physical, like the map in the example above, or abstract e.g. language. This also means that problems can be represented in various ways, making the solution more, or less, transparent. The ideal artifact should make us smarter (seen from the system perspective where [the user + artifact] is an entity), by restructuring the task at hand to be more manageable (which is the personal view of the individual using the artifact). Humans are not good at counting with large numbers or memorizing exact sequences of items. Nevertheless, modern life places demand on us to do such things, which makes us turn to artifacts. They can do this for us, or represent those problems so they fit us better.

The ideal artifact also has affordances for the task it is intended for, i.e. qualities that allow and invite the user to perform a correct action. Door handles afford gripping and pushing down, and chairs affords sitting on, but also digital artifacts have, or should have, affordances, because an artifact that affords the right action is easy to use. This, for example,
explains the popularity of touch interfaces such as those used in iPhones – they mimic the affordances of physical objects. What would you instinctively do if you wanted to scroll down a text that is too large to fit the frame in which it is presented? Would you push a minuscule little button with an arrow on? Probably not. Instead, one would probably physically move the text with your hand.

Hollnagel & Woods (2005) are not as interested in the cognitive aspects of certain artifacts, but in the impact the artifact and the use of it has on the larger JCS. They make a distinction between the *hermeneutic* and the *embodiment* relation (see figure 3), two categories of tool interaction, that are not mutually exclusive but rather a spectrum in which an artifact can be placed depending on the way in which it is used. When a tool is partly transparent, i.e. becoming a part of the user by amplifying an existing ability, there is an embodiment relation between the artifact and the user, which does not affect the control of the system. However, a tool can also be opaque, letting the user experience the world only as the artifact represents it, taking care of all communication between the operator and the process, therefore removing control in part. This is denoted a hermeneutic relation. For example, an abacus aids calculation in an embodied, transparent way, while a calculator hides the process of calculation, therefore removing control, being in a hermeneutic relation with the user.

![Diagram of Hermeneutic vs. Embodied Artifact Relation](image)

**FIGURE 3: The hermeneutic vs. the embodied artifact relation**

CSE is also concerned with the substitution myth, the assumption that when introducing an artifact into a system, it has no other effect than the intended. CSE instead claim that artifacts and technology can never be value neutral, and that one therefore must be careful when implementing a new artifact into a system, because it will make new tasks appear and old tasks change or disappear. This is closely related to the most important common denominator for the distributed cognition and the JCS perspectives - that tools do change tasks, work and organizations, rather than passively aiding the user in an anticipated way.
We will return to these concepts regarding artifacts in the JCS analysis of the initial trauma system. They are also brought up in the *Recommendations* chapter when discussing IT systems within radiology.
A brief introduction to medical imaging

Below follows an introductory presentation of the very basics of medical imaging for the reader who is not already familiar with this subject. The imaging techniques that are used within trauma care are briefly described, as are the IT systems that are currently employed for viewing and handling radiological images.

Imaging of anatomical structures has been an important part of medicine ever since the x-rays were discovered in 1895 by Wilhelm Röntgen. To see internal structures without having to make an incision in the body is a great advantage, and images are used in many disciplines. Most of the imaging techniques today employs x-rays, but not all of them. Below, the most common medical imaging techniques of trauma care is presented.

Radiography
The oldest and still most frequently used medical imaging technique is plain radiography (Erkonen & Smith, 2010). To obtain the radiograph, x-rays – electromagnetic waves of a certain wavelength – are sent through the anatomic site of interest to radiographically sensitive film, or in the more modern case with computed radiography, a phosphor plate. The x-rays will pass more easily through objects with lower density and be more easily absorbed by objects with higher density. Therefore an image will emerge, where high-density structure, like bone, will be white; low-density tissue, for instance fat, will be black. Plain radiographs are frequently used in the initial phase of trauma care, to obtain a quick overview of thorax and pelvis.

Computed Tomography
CT, sometimes referred to as CAT scan technology, was first developed in the 1970's. Since then, the technique has become more and more sophisticated (Lundström, 2007; Leidner & Beckman, 2007). The patient is transported, lying down, through the circular CT scanner, while the x-ray source and detector moves around him/her, enabling data “slices” of the patient to be acquired. Thickness of the slices vary between ten millimeter and less than one millimeter. Thus, CT produces data that can be used both as 2D- or 3D-images. No other single technique covers all anatomic structures as rapidly and sensitively as computed tomography (Leidner & Beckman, 2007). The downside of the technique is that the patient is exposed to radiation during the scan, and consequently there is always a trade-off between the benefit of getting accurate and detailed CT images and the risk of the radiation contributing to cancer later on in life (Erkonen & Smith, 2010).

Ultrasonography
The ultrasound technique provides sectional anatomic images by emitting high-frequency sound waves to the body via a transducer. The varying reflections are measured and interpreted to images by a computer. Ultrasonography has many advantages; being fast, safe, and cheap. It also enables viewing body images on a monitor in real time, as opposed
to the other techniques mentioned above, which merely provide images of snapshots in time. On the other hand the image quality is lower and the technique is not suitable for all anatomical structures. FAST, Focused Assessment with Sonography in Trauma, is a screening ultrasound examination performed bedside in the trauma room, used for discovering internal bleeding (Erkonen & Smith, 2010).

**Radiology IT today**

Previously, radiological images were viewed and stored as physical items. Today, technology enabling digital processing of the images is the standard in the developed world. For example, Sweden and the USA are fully digitalized markets in regard to medical imaging, and other European countries are not far behind (Nyström, 2011).

A PACS, Picture Archiving and Communication System, is a software solution enabling storage, retrieval, distribution and presentation of medical images. This has advantages to the traditional physical picture archives, in being more cost and space efficient and allowing remote and simultaneous access to the pictures from several work stations (Dreyer, 2006). It can also be integrated with other medical systems. A PACS is often used together with a RIS, Radiology Information System, where details and logistics about the patients can be managed. There are several providers of PACS and RIS worldwide.

In a typical scenario, the patient is referred to the radiology department, where he undergoes an examination based on the request of the referring physician. The data from this examination is reconstructed, i.e. post-processed, in order to from the axial slices obtain images in the preferred plane, or maybe even in 3D, on the modality station by a radiological nurse. There are also many preset filters used to improve the visualization, such as border enhancements, contrast tuning and color changes. The selected images are presented and stored in the PACS, which can be viewed on the radiologist’s workstation, which is an ordinary PC with a high quality display. The image data can be reconstructed and manipulated in the PACS as well, and the radiologist can zoom, rotate and view the image data in all possible planes. After reviewing the images, the radiologist writes a report which the referring physician can read via a web based referring system.
Research method and procedure

“The only instrument that is sufficiently complex to comprehend and learn about human existence is another human”. Jean Lave interviewed in Kvale (2007, p. 48).

In this quote, anthropologist Jean Lave emphasizes the value of the subjective researcher and her contextual interpretive powers while studying people and their activities. This contrasts sharply with the more traditional quantitative scientific methods. The quote elegantly summarizes the essence of the methodological framework of this thesis. This chapter covers the general research strategy of the thesis, as well as methodological choices and how the research work has been carried out.

Research strategy

Since the research questions of this study are of a highly explorative nature, a qualitative approach was chosen. To correspond to the theoretical framework, a field study “in the wild” granting high ecological validity was the highest methodological priority. Hollan et al. (2001) strongly suggest that research regarding human-computer systems should begin in ethnographic studies of the phenomena of interest. Hollnagel & Woods (2005) claim that to understand the general patterns of work, field studies must be conducted since the system as a whole is different from the sum of its parts. Hughes, King, Rodden & Andersen (1994) suggest a “quick & dirty ethnography”, i.e. brief ethnographic studies of smaller domains, to provide general but valuable information for systems design.

The research strategy combined field observations of actual trauma calls and a large quantity of interviews with key personnel in the trauma care chain, clarifying and explaining what was yet not understood. Hence, a form of triangulation between observations, interviews and literature was conducted, where each data source supplements the others to increase internal validity and add information to the results. However, the emphasis on interview data accentuates the phenomenological character of the study, i.e. that the relevant version of reality is how it is perceived by the people involved in it.

All thesis work, including interviews, observations, transcriptions and analysis was performed solely by a single researcher, the author of this study.

A brief pre-study was conducted before the field work began, in order to gain basic knowledge about trauma care and to define what to further focus on. Hughes et al. (1994) refers to this as familiarization fieldwork. Here it consisted of visits to the emergency department and emergency radiology unit at one of the hospitals later studied, and three introductory interviews with registered nurses and an anesthesiologist.

Choice of sites

The data collection took place at four Swedish university hospitals, all designated prime trauma centers in their respective regions. The reason for studying various trauma centers
was to check for variations within Swedish trauma care and to increase the external validity of the study. It was important to target university hospitals, since those are the largest, busiest and most influential. Also, only large hospitals in Sweden have the resources to organize complete trauma teams.

**Observations**

The observations were carried out at the two busiest hospitals studied. Naturally, trauma calls do not occur according to any regular schedule or upon request, hence the only possible strategy for observation was to spend significant time at the hospitals in question, and seize the moment when a trauma call did occur. Thus, overt, semi-structured observations were conducted. A covert approach was not an alternative, first and foremost due to ethical reasons, but also since it would have been impossible to spend time in the hospitals completely unnoticed. However, minimal attention was paid to the observer, since spectators are an ever-present part of the trauma resuscitation (see the *In the trauma room* section of the *The standard procedure of the initial trauma care system* chapter for details). The semi-structured practice suited the exploratory and inductive nature of the study, while completely unstructured observations were not applicable. After all, the study included pre-defined areas of interest and a certain theoretical framework.

Ten trauma calls of varying severity level were witnessed. However, a majority of them involved fairly isolated trauma and none of them was what could be called a complicated multi-trauma with immediate life-threatening injuries. The calls lasted between 30 and 70 minutes and occurred both during daytime and call time. Observations of both Trauma Room, CT suite and trauma care unit were conducted. The observation task was highly complex due to the number of people and tools involved and the lack of opportunities to ask the staff what was going on. Because of this, interpretation of the events was difficult.

During the time spent at the hospital, call handling and forwarding, operating facilities and a trauma radiology round were also observed. A fair amount of time was spent casually chatting with emergency and radiology nurses.

Notes were taken with pen and paper during the observations, and organized and written out on a computer within 24 hours after the visit to the site.

**Interviews and choice of interviewees**

Twenty semi-structured interviews were conducted with professionals working in trauma teams or in another part of the trauma care chain, in the four university hospitals that were a part of the data collection. Since the doctor workflow was the main focus of this study, the majority of the respondents were physicians. They were trained in the specialties involved in the core trauma team care: general surgery, anesthesia, orthopedic surgery, emergency care and radiology. However, a handful of interviews with registered nurses working either
on the team, in the CT suite or in pre-hospital care, were performed as well, in order to get a more holistic view of the system (for details, see list of respondents in Appendix). To speak with professionals from different specialties was important for several reasons. For one thing, this would provide a more objective and complete view of the subject studied. Secondly, since multidisciplinary collaboration regarding the CT images was within the focus of the research, it was critical to capture those aspects of the trauma work.

The interviewees were informed of the purpose and anonymity of the study. The interviews lasted between 30 and 75 minutes, the averaging being about 45 minutes. They were all conducted in person in the workplace of the respondents, with the exception of three telephone interviews. It was very important for the study’s reliability to actually meet the interviewees in person, since otherwise information and nuances in the discourse would be lost, due to the lack of body language and facial expressions. This also ensured a more dynamic conversation and likely had a positive effect on both the quantity and the quality of the information acquired.

The interview objective was to explore the pre-defined themes from the research questions, and gradually gain a better understanding of the overall workflow within the trauma care chain. Considering the inductive nature of the study, a semi-structured interview approach was chosen. Interview guides with prepared questions were designed and used, covering the themes of interest, but varying somewhat depending on the role of the respondent. The interviews were conducted as fairly informal but focused conversations; and questions were asked following the dialogue, rather than the other way around. Furthermore, the interview guides were slightly adjusted during the research, as interesting themes and questions from previous interviews arose.

All interviews were recorded, with the approval of the respondents. The material was transcribed at a word-by-word level, including retakes, roughly corresponding to a level II transcription (Linell, 1990), in order to permit a thorough analysis later on.

Analysis
The transcription of the interviews, observations and the reading of additional information collected at the sites, formed the first level of analysis, by introducing ideas and recurring themes. Then, all the material was printed and iterated over several times. During the initial iterations, “bottom-up” codes (Auerback & Silverstein, 2003), i.e. the emerging themes and general features, were created, categorized and applied to the material. This inductive method of coding, where the material somewhat speaks for itself, corresponds with the analysis approach of Grounded Theory (Glaser & Strauss, 1967).

Furthermore, the material also went through a “top-down” coding, i.e. with labels originating from the conceptual framework and the research questions. This double-coding was believed to enable a more thorough analysis of the data. Still, there were some overlaps
between the labels of the bottom-up and the top-down coding respectively.

In addition to the coding process, several ad hoc techniques of analysis of the data were performed, in a more liberal and less systematic manner. This includes visualizations of the data in diagrams and process flow charts, finding and interpreting discrepancies in the material and getting an overall impression from the various data sources. Kvale (2007) denotes this bricolage – to use the tools that happen to be available, even though they might not have been intended for the specific task at hand.
The standard procedure of the initial trauma care system

Below follows an extensive and chronological narrative of the typical initial workflow for trauma patient care at a Swedish university hospital, based on the conducted interviews and observations and – to a lesser extent – studies of written material. The reader should be aware that the description is a generalization and that scenarios differ among the hospitals in question. There is also variation depending on the specific patient case, and sometimes slight discrepancies between the interview and the written material versus what was observed. Such differences are described in the Variations chapter below. For a very brief summary of the patient flow, see Summary of the patient flow that follows this chapter.

Introduction

The overall goal of trauma care is to save the life of the patient. Approximately half of all trauma deaths occur immediately after the traumatic event, usually as a result of neurological injuries or exsanguination – commonly known as “bleeding to death”. About a third of the deaths occur during the initial hours after the injury, and the final 20% happen much later, within one-two weeks, and are generally secondary to multiple organ failure and sepsis, i.e. blood poisoning (Martin & Meredith, 2008). See figure 4 below.

FIGURE 4: Distribution of trauma deaths

The 30 percent second peak of deaths is the main target of modern trauma care (Martin & Meredith, 2008). Therefore, time is always a very important factor. This is manifested as the golden hour within emergency medicine, a concept referring to the importance of minimizing the lag between injury and treatment. The time frame in the expression does not have an absolute scientific basis; it merely reflects the statistical interference that survival is much lower 60 minutes post injury (Lerner & Moscati, 2001).
Since 1996, the concept of ATLS - Advanced Trauma Life Support, is used in Sweden. This is a standardized system for early care of trauma patients, developed in the United States in the late 1970’s by The American College of Surgeons, and is now adopted in over 50 countries worldwide, including all of North and South America, India, Australia, Indonesia, South Africa, Saudi Arabia, and most of Europe (American College of Surgeons, 2011). Courses are available for physicians, and in modified forms also for pre-hospital care providers and registered nurses. ATLS was originally designed for emergency situations where only one doctor and nurse are present. Now, in an adjusted form, it is also used at trauma centers where the patient is cared for by a whole team of professionals. The core concept is a structured, standardized treatment, addressing the most urgent threats to life first. The prevailing view amongst the professionals interviewed is that trauma patient mortality and morbidity has declined significantly after introducing ATLS. However, there is very little scientific evidence for this conclusion (Søreide, 2008). More on the ATLS in practice can be found below in the section In the Trauma Room.

**Call and pre-hospital care**
The typical trauma care chain starts with a call to the emergency call center, reporting one or several injured people. Depending on the distance, an ambulance or a helicopter is sent to the site of the event. If there has been inter-human violence involved, the ambulance often has to wait for the police to arrive before they can proceed with the assistance. Today, the main philosophy of pre-hospital trauma care is “load and go”, i.e. to after stabilizing the neck by placing the patient in a neck restraint, scoop him or her up on a spine board and under secure conditions go to the hospital as quickly as possible (R21). The professionals in the ambulance typically consists of a specialized registered nurse and an ambulance assistant and often do not have permission to anesthetize or intubate the patient.

After assessing the situation, the paramedics report their findings to the hospital, including information such as the nature of the incident, injury mechanisms, number of persons injured, and the states of the patients. This is mediated via a telephone or radio communication to the Emergency Department (ED) of the hospital. There are, depending on the hospital, two or more trauma call severity levels. The adequate level is assigned to the patient via a triage system based on vital parameters, apparent injuries, and the mechanism of injury. A major trauma is an obviously seriously injured person with affected vital signs; while a person exposed to high-energy violence but without clinical signs of having any severe injuries is considered a minor trauma. There are clearly defined parameters for this classification. However, there is a “better safe than sorry” approach to the sorting. The trauma call can be prioritized up or down to another level by any moment in the care procedure. It is more common that a patient is prioritized down, often after the initial examination, than the opposite case. Also, the spectrum of the definition of “major trauma” is wide, and can include any case from someone being kicked by a horse and having fairly
isolated trauma to the head, to a motorcycle accident patient with multiple severe injuries who is basically dead when arriving at the hospital.

As a rule, patients are transported to the main trauma center of the region, but if there is a long distance to the site in question and the patient is very unstable, he/she can sometimes be brought to a smaller and/or less specialized hospital.

**The trauma team**

At the hospital, the patient is rapidly transferred to the trauma room (TR), further described in the next section. Here the patient is cared for by a trauma team. Depending on the severity level of the trauma call, the composition of the team varies. If it is a minor trauma the team might just consist of an emergency physician or surgeon with the role of both team leader and examining doctor, and two or three nurses from the ED, while a major trauma calls for the full team, typically consisting of a team leader (L) who is a general surgeon; a primary examining doctor (E) who is either a junior surgeon or an emergency physician; an anesthesiologist (A); an orthopedic surgeon (O); a scribe; and several specialized registered nurses and assistant nurses (n). A radiologist (R) is also on the call, and may or may not be present in the TR – however, a registered nurse with specialty in radiology is always a part of the in-room team. See figure 5, below, for the typical placing of the team members in the TR for a minor and major trauma call respectively. Additionally, different consultant physicians may be summoned if necessary. All in all, the full team amounts to around ten people, sometimes a few more, sometimes a few less. In addition to the team, several people at other departments are indirectly involved in the initial trauma care, as telephones are frequently used in the trauma room and the CT suite. The purpose of the calls varies, and range from getting a hospital bed in a ward or asking for advice or additional support.

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**FIGURE 5: General placing of the trauma team professionals in the TR**
The roles involve different tasks and responsibilities. Roughly, the anesthesiologist is responsible for keeping the patient as stable as possible; the primary examining doctor is leading the clinical examinations in the trauma room; the orthopedic surgeon is concerned with fractures and other musculoskeletal injuries of the patient; the radiologist assesses the radiological images and the team leader monitors and directs the work.

The professionals in the team are on trauma call, and when the call coordinator of the ED pushes the trauma call button, they are notified by an alarm signal to their pager or the unit where they currently work. They then have to abandon the task at hand and leave for the trauma room, or if unavailable, send another person with similar competence. Depending on the distance from the ambulance or helicopter to the trauma center when the hospital gets the trauma call, the time span the team possess to prepare varies. As the team members enter the room separately, they put on protective clothing, and maybe present themselves and put on identification badges indicating their role within the team.

**In the trauma room**

The TR is a separate room in the emergency department, always prepared for receiving trauma patients with all equipment necessary for initial trauma resuscitation. Figure 6 shows the TR of a Swedish university hospital. Some TRs have space for more than one patient, and usually additional trauma units are available if necessary. There is a whiteboard on the wall on which a nurse writes some basic information about the call: when the call was received, the name of the trauma team leader, and sex, age and injury of the patient. There may also be a trauma checklist, which later will be referred to in the *Recommendations* chapter.
In addition to the team members, there are usually observers present in the room. The amount varies with the hour of the day, but the number can be considerable, primarily consisting of residents, interns, nurses in training and other staff or students interested in learning from the situation. They are not permitted bedside or anywhere near the patient or the core team, so they usually stand in a corner where they are as out of the way as possible. All in all, it is not unusual to find twenty people or more in the room, during normal office hours.

When the paramedics deliver the patient to the TR with the patient, there is a “silent minute” where they report the situation and all known facts about the patient and incident to the present team. Members of the team may also ask questions. At the very center of the TR is a stretcher where the patient is placed. The team take their assigned, pre-defined places around the patient (see figure 5 in the The Trauma Team section above), which is sometimes marked on the floor.

A central part of the ATLS system is a mnemonic, ABCDE, where every letter corresponds to a problem area addressed in the initial treatment and evaluation of the patient. The letters are in descending priority order and one should attend to them in that order, both to make
sure nothing is overlooked, and also to take care of the most urgent problems first. Below is a summary of the mnemonic.

- **A – Airways**: are the airways free or is something blocking them? Is there need for tracheal intubation?
- **B – Breathing & ventilation**: does the patient breathe by himself or is blood or air in the way? Examination of the chest.
- **C – Circulation & hemorrhage control**: does the patient have any external or internal bleeding?
- **D – Disability: neurologic evaluation**: Examination of level of consciousness, pupil size and reaction to light, level of spinal cord injury.
- **E – Exposure/Environment**: removal of all the patient’s garments, covering of the patient in order to prevent hypothermia. Systematic full body examination.

First, a very quick primary survey is carried out along the ABCDE system, to identify the most life-threatening injuries and start treating them. This may take just a few minutes, depending on which problems need to be immediately addressed. The different members of the team are responsible for various tasks, and there is often a pragmatic, semi-parallel approach to the ABCDE agenda, where each person focuses on a specified task, changing the originally “vertical” procedure to a “horizontal” procedure. The primary examining doctor is head of the survey and ideally calls out what is found relative to the ABCDE format, so the whole team can hear, while a scribe documents this in a form.

Following this, a secondary and more elaborate head-to-toe survey takes place in order to get a better overview of the nature and magnitude of the injuries. This examination is also highly structured, but is carried out more carefully and in greater detail. Also, the actions previously performed, if any, are evaluated. All in all, there is frantic activity in the TR. The garments of the patient are cut off, lines are put in, the vital signs are reviewed, and limbs are checked for mobility and fractures.

Sometimes a FAST, an ultrasonography examination focused on finding fluids in the lungs, pericardium and abdomen, is carried out. Not all hospitals have staff in the TR with the competence to perform an ultrasound. It is considered difficult to interpret the images and requires much experience – something that Swedish trauma professionals are not exposed to a high degree, which will be covered below. Ultrasound also has low depth penetration, which complicates the examination of obese people or those with deep internal injuries. Regular frontal x-rays of the chest and pelvis are often taken while the patient is still lying on the stretcher in the TR, depending on the need for them in the specific case. The resulting radiographs are immediately reviewed in the TR by the attending radiologist, or sometimes dismissed and not reviewed at all. If the patient is conscious, he is frequently spoken to, both to obtain information about his state and to explain to him what is happening.
During the procedure, the attending physicians have different roles, often supported by the nurses from the same specialty. The anesthesiologist is responsible for airways and breathing, and monitors the patient with the goal of keeping him stable. The primary examining doctor is leading the structural examination of the patient and performs most of it. The orthopedic surgeon focuses on fractures and other musculoskeletal injuries. If in the room, the radiologist reviews any radiographs taken there. The team leader has responsibility of the patient and for the treatment as a whole. She is often standing a few feet away from the rest of the team, having an objective perspective, a “helicopter view” of what is going on. It is the team leader that coordinates the team and has the final say in any decisions regarding the patient. She is also the one responsible for the strategy of the treatment.

When the secondary survey is completed, the team must make a decision about the next step. There are basically three alternatives: further examination with computer tomography, admission to the intensive care unit (ICU) or another ward, or immediate surgical intervention. A very large percentage – estimated to around 95% by the respondents – of the major trauma patients are sent to the CT scanner for further radiological examination. The ratio among minor trauma is less, but still a considerable percentage goes through a CT scan. A handful percent, being too hemodynamically unstable for a CT scan, undergo immediate surgical intervention. Minor trauma patients often must wait for the CT scan if there are a lot of other patients in the ED waiting for a radiological examination. Some minor trauma patients may have no or very slight injuries, and are sent to a ward for observation or even home.

The time spent in the trauma room varies significantly. The recommended time for unstable patients is a maximum of 15 minutes and for stable patients no more than 30 minutes. The team does not always succeed in keeping this ideal time spans, but are always striving towards a procedure as quick as possible.

**In the CT suite**

Many injuries cannot be diagnosed solely via a clinical examination, and therefore the CT scan is an important tool in the trauma care chain. Ideally, the CT suite is located in the immediate vicinity of the trauma room. However, this is not yet the case in all Swedish university hospitals. The CT suite consists of a room dominated by the large CT scanner (see figure 7). There is also special clothing to protect the staff from x-rays, and equipment for injecting contrast agents for enhancing structures or fluids of the body in the images.
Separated from the CT room by a glass wall, is the control room where the CT scanner is supervised and controlled (see figure 8). From a modality station connected to the scanner, various preset protocols and settings for the scan can be selected. Other equipment include at least one computer for picture archiving and radiology information – a PACS and RIS – and additional work stations connected to the scanner, where the pictures can be viewed and reconstructed.

At this stage, the original team begins to disperse. Depending on the patient’s injuries, it may not be necessary for the entire team to attend. Anesthesia (doctor and nurses) are usually present to monitor the patient, the team leader is always in the vicinity, and naturally the radiologist is there. Radiology nurses and assistants are also working. As a rule, the more severe the trauma, the more people occupies the CT suite. The size of the crowd in the room is also dependent on how busy the professionals are with other priorities at the moment.
The patient, anesthetized or awake, is moved to the “couch” of the CT scanner, which is moved up, down, forward and backward, to position the patient for imaging. The team leader decides which anatomical areas should be scanned, although the most common is a trauma-CT, a preset routine protocol including head, cervical spine, thorax, abdomen and pelvis. First a quick low-dose scan is done, resulting in a so-called scout image. This image provides an overview of the patient, valuable for the discovering of larger injuries in the extremities, but with the main function to provide information for orientation of the next, more precise, scan. Next, the body areas of interest are scanned in head-to-toe order.

As the scanning progresses, the resulting images appear at the modality station where the radiologist reviews them, and discusses the results with other members on the team. Typically, the radiologist sits at the screen, scrolling through stacks of 2D-slices and being in command of the work station. Other interested professionals are standing behind her, viewing the images over her shoulder and sometimes pointing at the images and/or asking questions to the radiologist. Few reconstructions are made in this early phase of care. 3D reconstructions are generally not used, with the possible exception of severe pelvis fractures, whose constitutions are often considered too complex to grasp in 2D view.

The primary purpose of the CT scan is screening for life-threatening injuries – such as internal bleeding in thorax/abdomen or hemorrhages in the brain – and to enable the prioritization of the most severe injuries. To map all of the injuries is secondary. Therefore, the radiologist goes through the images in an orderly manner, and for every anatomical area of interest, she preliminary either clears it or calls it. What takes place in the control room is consequently a primary, relatively quick review, where the information is communicated verbally to the team leader and other team members who may be present. In this review it is usually only the most prominent injuries that are found, and these findings are considered preliminary. The main objective is to determine if immediate intervention is required, and if that is the case, the important information for the surgeon, that can be deduced from the images, is the location of the injury.

The total time for the computer tomography survey varies, largely depending on where the CT suite is located. The actual scan is very fast, often just a few minutes, but patient transportation, transfer to the scanner couch and setting scanning preferences adds considerable time.

Based on clinical survey information and the CT scan results, the team leader determines the strategy for further patient care. Depending on the nature of the injuries, the local hospital culture and the specific individuals present on the call, a discussion based on the data at hand may occur. The decision regarding what to do with the patient is often made in a somewhat collective manner. However, this discussion may be very brief, down to 30 seconds, and the form varies considerably. Further details on this topic is found in the Decision making in the team section of the Analysis chapter below.
The alternatives for the patient after the CT are immediate surgery, or transfer to the ICU, to the trauma care unit, or to another ward. Some minor trauma patients are released. The total time for the examination in the TR and the CT examination ranges from 30 minutes to more than an hour.

**Post the initial attendance**

After the CT scan is completed, and the trauma team is dispersed, the images undergo a second review. This is done at the radiology department, and performed in a more detailed manner, by the radiologist alone. The results from this review are final, and documented in the RIS. This usually takes 20 - 45 minutes, but if there are several complex injuries, it may take longer.

The actual diagnosis of the patient is thus conducted in several steps or levels, where each step adds precision. The first rudimentary assessments are made during the primary survey in the TR, and actions taken at that point in time are solely based on these. More is known as the CT images are reviewed in the CT suite. However, as mentioned above, this judgment is not final, as the exhaustive radiological diagnosis is delivered later. Furthermore, any surgical interventions are not just treating the injury, but are a part of the diagnosis as well, since much is discovered and learned about the injuries during the operation. This is of course particularly true for those cases where surgery is performed before any CT examination is made, but surprises are found in stable and radiologically surveyed patients as well (Lennquist, 2007). Severely injured patients often have injuries in several organ systems and many of these are difficult to detect immediately, as they initially may exhibit none or modest symptoms. Therefore, continuous examinations and diagnoses are being done.

What happens with the patient after the trauma room and (if applicable) CT examination? There is no general answer to this question, as it depends on several variables: the injury, the hour, the individuals forming the trauma team and the local organization of the hospital.

Approximately 50% of the major trauma calls undergo some type of surgery at some point. But this could be any kind of surgical intervention, from stitching a small wound to making an incision in the abdomen, where such major surgery as the latter is quite a small part of the total number of operations. Moreover, only a fraction of the operations are performed immediately after or even before the CT examination – few injuries are so acute that they must be taken care of right away. Fractures are seldom immediately fixed, as they usually are not life-threatening. Instead, external fixations are often attached to the affected area, and the actual surgery is postponed for several hours, sometimes days, after the initial treatment. If the patient must undergo operation for more urgent injuries, it is important not to inflict excessive surgical stress on him, which can contribute to other treatment delays. However, orthopedic surgery is a key part of the trauma care chain, as the treatment of orthopedic injuries often determines the resulting quality of life for the patient. It is common for the
patient to first be waiting in a care unit and then proceed to surgery within the next 24 hours, sometimes even later. It is also common to be staying at the ICU or a trauma care unit for careful observation, as some injuries do not manifest themselves immediately. Many complications also do not require surgical intervention at all, but can be handled medically.

When the trauma team disbands and the patient is transferred elsewhere, relevant information about him naturally has to be reported to the receiving party. This is also the case when the staff involved go off their shift and another person takes over this role. Reporting is done in a multitude of ways depending on the organization of the hospital in question and where the patient is going. If there is need for immediate invasive treatment, the team leader is usually heading the operation or at least a part of the surgical team in the OR, and thus naturally bringing the information with her. If the patient is transferred to the ICU, the anesthesiologist delivers the patient and reports to her colleagues there. For other wards, the trauma leader may report by phone or in person. Sometimes reports are done separately within the professions, i.e. nurses report to other nurses and the doctors to other doctors. During this research, it has been hard to grasp how information flows at this point and it seems like routines vary or sometimes are lacking. This is discussed further in the Recommendations chapter.
Summary of the patient flow

Figure 9 and 10, below, summarizes the typical patient flow of a minor and major trauma call respectively.

**FIGURE 9: Schematic minor trauma patient flow**
The patient flow is not always linear but can sometimes be iterative. For example, a patient that is so hemodynamically unstable that his injuries must be addressed before a radiological examination can be performed, may go to the operating room (OR) immediately from the TR and only then be transferred to the CT suite.
Variations
In spite of ATLS giving the trauma care a certain standardized flavor, there are substantial differences in how a trauma call is handled, depending on several factors. Those variations are referred to in the following sections as well, but are summarized in this passage.

Variations within the trauma center
The state of the specific trauma patient and the nature of his injuries naturally influence how the call is handled. If the patient has multiple injuries, deciding upon proper treatment can be more difficult, since the team must prioritize among the injuries. Generally, a more isolated trauma implies less ambiguity and a more straightforward choice of care. A severely injured patient in extremely urgent need of care, also changes the situation in the trauma room. The great majority of the respondents claim that the team actually performs better when dealing with such a serious case, both in terms of efficiency and effectiveness. The seriousness of the situation is said to increase the orderliness of the procedure and make the team members more focused. However, some informants claim that the team is affected in a negative way by the extra stress the critically injured patient brings to the room – that the procedure might be quicker, but the quality somewhat drops, since the professionals involved become more upset and nervous.

That the individuals of on the team have a big impact on the overall team performance is beyond doubt. All respondents bring up this subject. Competence, previous experience, interest in trauma care, social skills and sheer personality of the trauma team professionals vary significantly from call to call and all these characteristics play a major role in determining how and how well the team is going to work. This affects efficiency, communication and general flow of work. The personality of the trauma leader is said to be critically important, which is addressed below in the Leadership and group dynamics chapter.

The time of day when the hospital receives the trauma call might slightly alter the work. The goal of major Swedish trauma centers is that this should not influence the result, and that the patient will receive the same care no matter when the injury occurs, but after all, there is less staff in the hospital at night time and weekends. At university hospitals, all necessary professionals for the trauma team are on call all around the clock, but they are often more junior than during the daytime. There are also fewer hands if the hospital admits several injured patients at once. However, there is always more senior personnel available in backup capacity, who can be consulted via telephone or available in the hospital on short notice.

Variations among the sites studied
There are differences between trauma care among the Swedish hospitals which have been subject of the research. The number of call levels can be two or three, and participating roles in each level vary as well. It is most common that minor trauma calls are handled solely by one doctor from the ED and two nurses/assistants, but in some sites there may be more staff
involved. One of the sites visited had just removed the orthopedic surgeon from the major trauma team, as this role was considered superfluous in the initial treatment. Another hospital always staff two anesthesiologists during a major trauma call, one from the ICU and one from surgery. At yet another, the roles of the team leader and the examining doctor are handled by the same person. Some sites have an emergency physician, when available, serving as the primary examining doctor of the team, and some have exclusively surgeons for this role. It also varies if the radiologist is present in the trauma room, or just arrives to the CT suite when it is time for the computer tomography.

The location of the CT scanner relatively to the TR appears to greatly impact the trauma workflow. Few hospitals in Sweden have the scanner in immediate vicinity to the trauma room, even though this is the new standard when building or rebuilding trauma centers. Instead the scanner is often located in the radiology department, which may be a considerable distance away. Some of the respondents believe that the location of the CT scanner does affect the ratio of the trauma patients scanned and some postulates that it does not, but all respondents working at trauma centers where the scanner is not in junction with the TR agrees that this is a nuisance and causes unnecessary time losses when transporting the patient to another area of the hospital.

Not all trauma centers are using the same computer systems for radiology and documentation. The system providers vary, as does the satisfaction of the users. There are, however, no notable variations observed regarding the core workflow of the systems.

How trauma care is prioritized internally also varies among hospitals. At some sites there tends to be more staff interest in trauma care, which increases the local status of that domain. Interview data indicate that this may influence organizational issues, and definitely influences teamwork. This issue is being further addressed in the Detected problems and difficulties chapter below.

Variations abroad
The valid conclusions about trauma work abroad are limited within this study, as all information regarding this issue is derived from literature or interviews with Swedish professionals. Still, this brief section is dedicated to this subject, since some differences between Swedish trauma care and its counterparts abroad was frequently brought up by informants.

The main distinguishing feature of Swedish trauma care is that the frequency of trauma calls is very low relative to other countries, thanks to a small population, active traffic safety development and a low level of violence and assault. The largest trauma center in Sweden averages roughly one major trauma call per day, which is significantly less than the bigger trauma centers of for example the United States. This means that Swedish trauma professionals receive considerably less practical experience than their colleagues abroad, a
problem addressed with simulator practice and the like. It is also common for Swedish doctors interested in trauma to work in a foreign county, for some time, where the trauma frequency is higher, in order to compensate for the lack of practical experience at home.

The low trauma frequency also means that professionals at a Swedish hospital never can work exclusively with trauma – this simply cannot be motivated with regard to insufficient work load and economics. In countries were trauma is more common, there are for instance surgeons operating solely on trauma patients. Despite this, Swedish trauma care is considered to more or less match the performance of its counterparts abroad, according to its own practitioners.

Possibly because of the relative lack of injuries and accidents, Swedish emergency care in general is considered to be lagging behind, at least in comparison to the Anglosaxian world. Emergency physicians did not exist as a specialty in Sweden until the beginning of the 21th century, and hence emergency care has traditionally occupied a fairly low status. At the Swedish hospitals where specialized emergency physicians are hired, they are being incorporated into trauma care as primary examining doctors.

The exact composition of the trauma team varies a lot among different hospitals in other countries, but there are not many significant deviations from the core roles; the team leader, the primary examining doctor and the anesthesiologist. In Sweden, the trauma team leader is always a general surgeon, but this is not the case globally, where the team leader is often an anesthesiologist.

Culturally, the professionals interviewed believe that Sweden stands out as less hierarchical and having shorter power distance than other countries. This means that the strong leadership considered necessary in trauma care might be culturally uncomfortable for some, but a flatter organization may also mean that it is easier to communicate between the different specialists and professions.
Analysis
The findings of the previous chapter serves as a starting point for the more elaborate analysis. However, this part of the thesis is an interpretation rather than a description of the initial trauma care system. The conclusions of this chapter are derived from the bottom-up and top-down coding of the collected ethnographic data, if nothing else is stated.

The analysis chapter consists of several parts. Below, the first section summarizes the most prominent features of the initial trauma care system. Then two sections, emphasizing leadership and decision making – two subjects of interest relative to the research questions – respectively. After that, the initial trauma care system is analyzed as a Joint Cognitive System. Finally, problem areas within the initial part of trauma care are discussed and summarized.

Features and characteristics of trauma work
Below is a short presentation of the most prominent qualities of initial trauma care. All topics are subsequently discussed in context further in various sections in this thesis, but this section provides a summary.

The limited time scale
The work within trauma discipline has a very well-defined goal: primarily to save the life of the patient, and thereafter to prevent long term disability. The procedure of initial care reflects this objective, as the focus is on quickly locating critical injuries rather than mapping all patient injuries. Contrary to what the layman may believe, few injuries are immediately life-threatening, even though they are highly distressing for the patient. This applies to most fractures, for example. To reach the goal, time is of the essence. Therefore, a sub-goal of trauma care is to decrease the timescale of the workflow.

The highly structured performance
A characteristic of the initial part of trauma care is that it is highly structured and standardized. There are certain strict procedures the team carries out without any need for much deliberation or discussion, and pre-defined alternatives for decisions to be made. Accordingly, the initial workflow is to a high degree the same, no matter the nature of the injuries.

The main reason for the structured procedures is, in addition to saving time, to avoid overlooking a critical injury of the patient. Just as a clearly perceptible injury may not be life-threatening, the critical injuries are not always immediately apparent. “It is easy to fail to discover the dangerous injury, and instead notice the dramatic injury” (R12), a junior anesthesiologist says.
The need for broad expertise and a team approach
Since the patient potentially could be injured anywhere, the patient must be screened from head to toe for a wide range of injuries. This makes trauma a field where it is important to have broad expertise rather than high specialization, both for the individual and the group. Hence, there is a fundamental need for a team approach in trauma care. The care is a highly distributed process, both in a cognitive and a practical sense. The collective knowledge of the team would be impossible to summon in a single person or smaller group, as would the sheer number of hands. A senior anesthesiologist says:

“Even experienced trauma team leaders – you know, it is not possible to work with this if you don’t work in teams. In that case you won’t be here long, I can honestly tell you that. You have to understand that if you’re gonna take care of patients this badly injured, you can’t make it yourself” (R13).

Depending on specialty, an interest in various injury features and conditions of the patient are evident. This is important, because if a certain expertise not is available, attention may not be focused on a critical injury.

The importance of experience
Experience is a constantly recurring theme in various forms in the interview material. Experience-based handling is widely recognized in health care at large. Many treatment procedures and practices are not based on scientific deductive research, but have been developed through clinical empiricism over the years and are being passed on from one professional to another. Thus the trauma team constantly acts on the experience of others, but it is also crucial to perform hands-on care to develop competence. For example, an emergency physician says:

“You can’t go home and read a book you know, you have to work with it” (R15).

According to the informants, professionals with more practical experience are more competent, better at teamwork, better at the trauma procedures and possibly better as leaders. A majority also claims that experience is highly important when it comes to making decisions and diagnosing the patients. That experience develops expertise is probably news to no one, but seems to be particularly true within trauma care.

Additional experience is also one of the most frequently mentioned subjects when informants are asked how trauma care could be improved.

Leadership and group dynamics
As leadership and its varying quality seems to have such a big impact on the trauma team work, it will be further explored in this section.
Since trauma work is not scheduled, the team line-up is somewhat random – the team will consist of individuals who happens to be on duty at the moment the hospital receives the call, and is reconstituted each time. This makes the trauma team different from many other teams, in that it is dynamic and exists only for a very brief period of time. Many participants often do not know each other. At most trauma centers team members are supposed to wear badges stating which their role are, but it is not always complied in practice, and then it is sometimes difficult for participants to understand who is assigned to which role. For example, at one trauma call observed, the anesthesiologist was seen shouting “who is the radiologist here?” Working in unfamiliar teams also means that one often does not know the capacity of the other team members.

In order to perform optimally under such circumstances, not to forget the time pressure and the stress of dealing with life and death-situations, the team is in a great need of a coordinating leader role. Some participants on the team may be in training or fairly novice in trauma situations, which further adds to this need. The vast majority of the respondents claim that team performance is highly dependent on the team leader. This is consistent with previous studies on group dynamics in trauma teams (Cole & Crichton, 2006). However, a competent team can compensate for a weak team leader, and vice versa. This is substantiated in both the interview material and the observations. When dealing with a critically injured patient, the importance of the leader role increases. An emergency physician says:

“The main purpose of that person [the trauma leader] is really to direct the forces and make general decisions. That function is great. That function is completely crucial. And it’s more crucial the worse that patient is” (R15).

The team leader has the formal responsibility for the patient, and her role is first and foremost to conduct the orchestra – to collect information from the other professionals in the team and maintain a comprehensive view of the situation and the patient’s injuries. The team leader is responsible for making treatment decisions, in consultation with and with support from the other doctors present. She also has to make a final decision when there is a need to differentiate between alternatives of equal forecasted outcomes. There is usually no need for instructing individuals, as the team members are proficient and everyone know what tasks their roles imply, but the leader still has to coordinate the overall process and sometimes push the pace, in particular when involving consultant specialists who may not be that familiar with urgent situations.

In Sweden it is always a surgeon, often a general surgeon, who has the role of team leader. This because it is generally considered that the only person authorized to make the decision of a surgical intervention, is the person that is going to perform the operation. Each hospital has usually just a few senior trauma team leaders, and they work during daytime, as a rule.
This means that the formal competence of the team leader varies significantly, from residents to senior surgeons. However, if the team leader is a resident in training, a more senior surgeon may be present as well as back-up. How often a certain team leader participate in a trauma call also varies between individuals. The senior surgeons with a dedicated interest in trauma gets hands-on experience fairly often, while some surgeons who are on trauma call just a fraction of their time may get just a few calls a year. Naturally, this affects how comfortable the person is in a leadership role.

The informants agree on the fact that leadership varies significantly with the individual, as do the other team roles. This has a big impact on teamwork. An anesthesiologist states:

"It [the leadership] is very, very dependent on the individual. It is tremendously so actually. From textbook examples to simply chaos. Either that they don’t do anything, or that they do too much as a team leader. It is the whole spectrum" (R11).

Those who are considered lacking as leaders are either too dominating or too weak in their leadership, where the latter is much more common. It is believed that failing to take on a proper leadership role often has to do with disinterest in the trauma situation, when unwilling junior doctors or residents are put in the team as a part of their training.

To be firm, distinct and apparent are considered the most important qualities of the team leader. The ideal team leader should master the balancing act of being authoritarian yet perceptive of the opinions and expertise of the other team members. She should have the ability to adjust the leadership style relative to the situation, to delegate when possible and act more directive when needed to. But first and foremost the leader must be strong in her role.

The leadership role of the trauma team is despite the title nothing that comes automatically, but has to be claimed. If the official leader does not take command and demonstrate that she is the one in charge, perhaps because she is junior to other members of the team or due to personality, other members may unofficially take over the leader role. This is also noticed in Berlin & Carlström (2008), who made a longitudinal study of trauma teams at a Swedish university hospital. They cite an example of their observation material, where a team leader fails to take initiative and an anesthesiologist does this instead. The result is that the anesthesiologist has an implicit veto and the official team leader’s orders must have her support. Similar events have been observed during this research.

The anesthesiologist(s) is often the person that is closest to the team leader in the trauma team hierarchy and is the most likely to take over or compete for leadership. She directs her nurse anesthetists and hence already has a leading role in a sub-team within the larger group. Additionally, the anesthesiologists claim better knowledge in and more experience of handling extremely ill and unstable patients, as they often work at the ICU or peri-
/postoperative while not on a trauma call. Confirmed by other professionals, this knowledge is considered very valuable. However, since it is not always obvious when a trauma patient is actually quite ill, tactical opinions can differ between the anesthesiologist and the team leader, which could present minor conflicts. The informants do not bring this up as a real problem, though.

Many of the most appreciated team leaders have a kind of natural authority in the trauma room. This seems to stem partly from experience and age, but also personality. Several of the informants believe that this is an absolute trait associated with the person – either you have it or you do not, it is not something that can be learned. However, voices are raised that this might not be the case, and that there are strategies for good leadership development and that these skills can be practiced and learned. More regarding this issue can be found under Detected problems and difficulties below.

At most hospitals the role of the trauma leader is such that she should generally not touch or handle the patient in the TR, unless she is more or less forced to intervene; for instance if the leader is the only one present with a certain competence. This is considered very important, as it enables a high level comprehensive view which is crucial for control of the situation and making the right decisions. Several interviewees attest to the difficulty of maintaining a general picture and process of all information when bedside, because dealing with the patient considerably narrows the focus. That divided attention usually implies poorer performance is acknowledged in cognitive psychology (several studies indicating this are listed in Sternberg, 2006). Some hospitals, one of four in this study, do however have a different approach to the team leader role, where the same person takes on the role of primary examining doctor and team leader. Some respondents claim this is a more efficient way to perform the initial survey.

The trauma team is positively hierarchical, possibly more so than in other constellations in healthcare. Several respondents remarks that this is something that does not correspond very well with the cultural climate in Sweden, where we are not used to such strict roles and uncompromising leadership. Regardless, it is something that almost everyone wants in the trauma room. This leads to a sort of paradox: most doctors want to participate in the decision process, but many do not feel comfortable with taking on an official leadership role. It is common to not have courage to accept the right to decide and clearly show the way.

Klein, Zigert, Knight and Xiao (2006) studied trauma teams at a trauma center in the United States. They found that leadership in this context was established by a rigid hierarchy but at the same time flexible – which allowed effective leaders to delegate and step back, while at any point in time reclaim a stricter and more directive leadership. They also discovered that the trauma leaders studied did not have to perform some of the tasks typically associated with leadership in other teams. Team members did not have to be motivated, since the resuscitation situation itself is inherently motivating. Norms and routines did not have to be
established, since each team existed for such a brief time span. Such structures could instead be found in the trauma unit as an institution, something that very much corresponds to findings of this study.

**Decision making in the team**

The great variety of condition and injuries of trauma patients makes the trauma call a highly complex situation. However, the standardized approach initial treatment, supported by the ATLS and local policies, simplifies the decision making significantly. The team does not have to constantly question what to do next. Hollnagel (2007) writes in the anthology *Decision making in complex environments* that a procedure is an externalization of decision making, so the system can concentrate on when to do something rather than to struggle with finding out what to do. This is true for the trauma team as well. Nevertheless, there are definitely decisions to be made, and those are often but not always done at certain stages of the treatment: after the clinical survey in the TR when deciding if there is time and a reason for a CT examination of the patient; and post this likely CT scan, when prioritizing among injuries and devising a strategy for the further care of the patient. There is also the possibility of having to prioritize the patient to another call level, or having to perform immediate emergency surgery. After the initial treatment, many other decisions must be made regarding the continued care, but these are not within the scope of this study.

The team leader is the one ultimately responsible for the patient and has the final say in any treatment decision, but the decision making is typically socially distributed. To what extent varies though, first and foremost depending on the professionals involved. Some team leaders prefer to make as autocratic decisions as possible, as this is considered more efficient, while other team leaders are more likely to initiate discussions. When the team leader is more junior, the decision making tends to be more distributed. Also, some situations call for more discussion than others. If the patient has multiple injuries, there may be a greater need for consulting other specialists, and when an ethically difficult decision is required, e.g. an amputation, a conference is necessary. If the patient has only minor injuries, the only doctor of the TR team remaining after the CT scan may be the team leader and then there is of course not much of a dialogue. When the team is faced with equally good/bad alternatives, it is also the team leader who makes the choice between them.

> “The team leader should be the driving force of the team, and the others should provide creative ideas, based on their expertise” (R5).

This quote describes what is considered the ideal and standard form of decision making: the team leader weighs in on the results of various examinations performed and input from the other doctors present, in order to come to a conclusion. The other doctors may be asked questions or suggest an alternative to what was advocated, which could make her change direction. It is very important for the team leader to obtain support for her decision, both from the known information and from the other team members. However, when the team
leader’s decision is final, everyone accepts it, which is considered crucial. The TR is no room for criticism; this can be delivered later, in a non-urgent situation. Hence it is very unusual for open conflict to occur during the initial care of the patient. The opinions regarding what the best way is to make decisions varies among the informants; however, the great majority thinks it works well, and everyone seem to acknowledge that democracy is not an alternative, as it would put the patient at risk. Professionals who are not doctors are generally not involved in major decision making processes.

As described, the situation is complex, with a multitude of variables to take into account when making a decision. There is no general strategy or technique that is applicable neither for all situations, patients, injuries or professionals involved (Lennquist, 2007). Generally, the actual state of the patient is not completely known and often subject to rapid change. Hence, a paradox appears: there often is excess information – or at least too many variables to effectively consider them all – while at the same time the material for decisive support is lacking. This makes it extremely difficult for the team to make the completely logical, deductive decisions humans are assumed to make by traditional economic theory. Hollnagel (2007) postulates that traditionally considered “rational” decision making never can be performed in a complex system, because a major principle – that the subject is completely informed – cannot be achieved in a highly dynamic environment. Complete information in this context can only be obtained if all the necessary information is sampled so fast that nothing changes while the sampling takes place. This is clearly impossible in the trauma call situation – the informants emphasized that one of the major disadvantages with radiographs and CT images is that they are limited to a static picture of what is going on inside the patient. Lennquist (2007) writes that the trauma team constantly has to make decisions based on incomplete data.

The informants describes this as there certainly exists “wrong” decisions in the TR, but not any indisputably “right” ones until in hindsight. Due to this uncertainty and lack of time and information, experience is an ever-important factor when making decisions in the trauma team. This cannot be overemphasized. “More clinical experience” is referred to as the single most important factor for improving the performance of the team, and more experienced individuals frequently takes a more prominent role in the team’s decision making.

Several respondents refer to something called “clinical eye” when asked about the decision making process of a trauma call. Clinical eye is a notion difficult to define, but is described as implicit knowledge; a mix of experience, empathy and intuition, and relates to the general perception of the situation beyond what is apparent. Some doctors have a better clinical eye than others, but it can be developed through practice. When using the clinical eye, the doctor notices subtle details that easily could have been overlooked, but are critical in the context. It is difficult to verbally explain why a certain action based on the clinical eye is done - it is a
“gut feeling”. This concept possibly corresponds to what Goodwin (1994) calls professional vision - the notion that an expert in a given area due to experience literally do perceive the world differently compared to a novice, and therefore performs in a superior way and with more ease. The importance of experience seems to increase as the state of the patient declines. In very acute situations, the time for collecting and processing information is less, and the decision maker has to rely more on her and the team’s collective experience.

The role of experience and intuition in decision making has traditionally been overlooked in economic-, game- and decision theory, but is acknowledged in more recent research. Numerous studies show that people constantly base their decisions on heuristics, different cognitive short-cuts for reasoning that is based on experience (for a review, see Sternberg, 2006). Such inductive reasoning saves time and computational load and results in conclusions and decisions which are often successful but not strictly logical. There is also increased support for research suggesting that humans actually have two separate systems of reasoning (Sloman, 1996; St Evans, 2003; Naqvi, Shiv & Bechara, 2006). System One is a set of sub-systems, consisting of both innate properties and domain specific knowledge. It is fast, associative, affective, implicit, inductive, older and shared with some other animals. System Two is more evolutionary recent and slower, rule-based, logical, and explicit – corresponding to the traditional notion of reasoning. The two systems are working in parallel, hence they are competing. One system is not necessarily better than the other, but each have different advantages. System Two makes more logically rational decisions, but has more difficulty in dealing with complexity. Dijksterhuis, Bos, Nordgren and van Baren (2006) showed that subjects made objectively better choices and were more satisfied with choices made consciously (system two) when the problem was simple and well-defined, and with choices made with a “gut feeling” (system one) when faced with a more complex and information dense situation, naming this the deliberation-without-attention hypothesis. The findings in this thesis work suggests that professionals in the trauma team certainly make use of heuristics and system one reasoning when making decisions, due to the huge complexity of the situation and lack of time and information.

Lack of time also implies stress, which can worsen the ability to make correct decisions. The negative impact of stress on the cognitive capabilities of humans is well documented. For example, Kontogiannis and Kossiavelou (1999) studied teams, concluding that stress decreased their vigilance, reduced the capacity of working memory, caused premature closure in evaluating alternative options, and resulted in task shedding. However, the majority of the respondents denied this, instead claiming that the team often performs more efficiently and effectively when dealing with a very urgent case. Maybe being accustomed to working in stressful conditions improves the trauma team professionals’ ability to perform under stress. Kowalski-Trakofler, Vaught, and Scharf (2003) writes that judgment is not always compromised under stress. Stress may narrow the focus of attention, but this might
be a positive in decision making, by enabling people to adopt a simpler model of information processing, that helps in focusing on critical issues.

The equipment measuring vital signs is central for the professionals when determining what to do and how to handle the patient. Beyond this, the decision support provided by CT images is acknowledged, and being able to perform a CT examination of the trauma patient is often considered crucial, even though there are situations where this is not possible and therefore must be compromised. However, in the initial part of the treatment, it acts first and foremost as a support for binary decisions – whether there is a need for immediate surgery or not. More on this is found in the Recommendations chapter of this paper. The ultrasonography examination that may take place is also considered as a good decision support when performed successfully. The problems with this technique are that competence for performing an US is not always present and that it can only be used for a limited number of anatomical areas. Considering that CT images have a much higher quality than the US counterpart, CT is therefore considered a more valuable decision support.

The trauma team as a Joint Cognitive System

“I tell you, nobody can be in full control of a trauma room at all times” – (R2), senior general surgeon and trauma team leader.

In this section, the initial trauma system is analyzed according to the model of Joint Cognitive Systems, earlier mentioned in the theoretical framework. In order to aid the reader’s comprehension of the concepts of control within Cognitive Systems Engineering, the figure of the Contextual Control Model is presented once more. See figure 11 below.
According to the delimitations of the scope of this research, the system studied is limited to the urgent trauma situation and the initial care of the trauma patient. Thus, the JCS described consists of the staff, premises, equipment and instruments involved from the moment the patient arrives to the TR, until the patient is transported from the TR/CT suite to emergency surgery or a care unit. Explicit or implicit procedures, rules, habits and other cultural phenomena locally advocated at the hospital is also a part of the JCS.

As stated above in Features and characteristics of the trauma team the overall goal of the initial trauma care is clearly defined: to ensure the survival of the patient. This entails various subgoals, e.g. performing a successful intubation, discovering fractures or documenting the results of surveys, etc. However, the main goal is unusually explicit, uncompromising and uniform for such a complex system, and thus all functions of the system are relatively hardwired to it. This goal is never changed or modified, as opposed to the system. For the JCS itself, or at least its conditions, are constantly altered, as individuals vary and roles come and go, not to mention that it is reborn every time the hospital receives a trauma call. This complicates the task of controlling the processes, a difficulty which is met by providing rules and procedures, both explicit and implicit, such as the ATLS. This in turn allows the units of the system to be more interchangeable, something that of course is encouraged when having the JCS perspective in mind, as the focus is on functions rather than units.

Despite these challenging circumstances, the cognitive components of the JCS are highly intertwined and collaborative in the immediate geographical vicinity of each other. Thus, the “system-ness” of the trauma team is very apparent even to the untrained eye. The dependency is, however, asymmetrical. The more basal subsystems, such as the assistants and the registered nurses, can perform their tasks largely independently of the other team members, while the team leader to a great extent relies on the others’ performance. Often the nurse and the doctor in a certain specialty, for example anesthesia, form a subsystem together, with shared functions and subgoals.

External artifacts - such as various instruments, patient monitoring systems and radiology equipment – are used frequently and generally for its intended purpose. However, the system is not very dependent on most of them – it is the competence of the cognitive components that is crucial for reaching the goal. A majority of the artifacts used in the TR are embodiedly related to the users, as the most of them are not used cognitively but as tools to manipulate the physical environment with. Hence they become a kind of extension of their own bodies and their own capabilities. The professionals could complete most of the primary and secondary survey without much of the equipment, even if the procedure then would be slower and less exact. However, the CT systems are clearly hermeneutically related to the trauma team, as the level of transparency for these artifacts is low. The CT scan interprets the inside of the patient for the physicians, and there is no way of seeing this
translation process. It provides information that would be impossible for the doctors to obtain without the artifact, but at the same time, it does decrease control.

The controlling system of the initial trauma care is dominated by the team leader, but is still distributed over monitoring equipment measuring vital parameters and the other staff being consulted. The controlling system is also formed and supported by the team hierarchy. As described in the Leadership and group dynamics section, at any moment main control can be taken over by other cognitive systems present.

Sometimes it is unclear what is feedback and what is feedforward in the control process. For example, since the doctors on the trauma team rely on experience to a high degree, one may argue that they are therefore practicing a feedforward approach. On the other hand, according to the possible existence of two systems for reasoning, as was reviewed in the Decision making in the team section previous in this chapter, it may as well be that the doctor is responding unconsciously to information from the current situation, when using a “gut feeling”, which is feedback. In practice, it is likely that a combination of feedback and feedforward is used in these cases. What is common, regardless of this, is the time-related stress the system performs under – there is a constant shortage of time. This means that the trauma team as a JCS cannot rely solely on feedback, since there is simply not enough time to interpret and analyze the information. Instead, the team applies feedforward by using the abundant source of experience in the system and by practice predefined procedures.

Hollnagel & Woods (2005) writes that lack of time is in the nature of any system dealing with a dynamic process and/or a dynamic environment, and that this weakens the controlling system’s ability to process the feedback and predict the future. The trauma team represents an extreme case of this condition, as time not just is sparse but a sub goal itself is to shorten the time span. This means that it is difficult for the controlling system to form a valid construct of the situation, which in turn may enable it to choose sub-optimal actions or strategies for the patient, which further affects the scenario. There is also frequently a lack of information when forming the construct, partly due to the mentioned time-constraint which does not permit a completely thorough examination; but also because the body of the patient is opaque and extremely complex – even if the whole body can be imaged, some features, relations and processes will still be missed or not understood. When untrained or inexperienced staff, such as residents, are put in central positions, this may negatively affect the interpretation of events, and hence the construct. This causes some instability in the system, but is not that significant, since there are always other resources – within the team or outside of it – with the appropriate level of knowledge available for consultation.

It is apparent, however, that this JCS is not – and cannot be - in control all the time. There is risk-taking and decisions based on lacking information involved, something that is confirmed by respondents. For instance, see the quote from an experienced trauma surgeon at the beginning of this section.
The JCS simply does its best under the current circumstances, which sometimes is enough, sometimes not. Hollnagel (2009) writes about something called the ETTO principle, an abbreviation standing for Efficiency-Thoroughness Trade-Off and denotes the ability to adjust work to match the current condition, when resources such as time, information, material or energy are in short supply. Since there is always a trade-off between how thoroughly something can be done and what is reasonable to do given the current circumstances, this strategy is found in most environments. However, the ETTO principle is especially applicable to the initial work with a trauma patient. Lack of time and information constantly forces the trauma professionals to compromise thoroughness and relinquish some control. For example, all radiologists interviewed said that it is difficult to determine how careful one should be when making the first, quick review of the CT images; since time is limited one cannot be completely thorough. Another example is that the trauma staff constantly has to weigh their other tasks at the hospital against the benefit of staying longer with the trauma patient.

The ETTO principle is especially prevalent in the decision making process, where it is impossible to make completely informed decisions. More on this is can be found in the Decision making in the team.

Detected problems and difficulties
This section documents general problems and annoyances highlighted by the respondents during the interviews, and noticed during the observations. However it should be noted that the opinions among professionals vary greatly on some issues.

Dependency on the traits of individuals
A very salient feature of the trauma care situation is how dependent it is of the individuals forming the team, as discussed above in Decision making in the team section. This affects all areas of work: the communication, collaboration, decision making and general performance. These individual differences are considered especially prominent when it comes to the team leader, since this role has the single greatest impact on the team as a whole. It is generally considered a problem when all team members cannot measure up to the same standard. For example, a senior anesthesiologist says:

"I would say that is our biggest problem right now, the diverse leadership. We have team leaders that are just excellent; competent, knowledgeable, take their role very seriously and handle it well. And then we have the opposite as well. Often based on disinterest of the situation. They are put where they don’t really wanna be” (R10).

On the other hand, most of the professionals interviewed consider this a necessary evil to a certain extent, as the trauma centers are part of teaching hospitals, and the only way to learn and obtain valuable implicit knowledge that experience provides, is to actually practice in a real live situation. Therefore, all staff cannot, and should not, be equally competent. When a
more junior professional is on call, as a rule, more experienced staff are involved as well. Typically, the collective competence of the team is something that levels out.

At least this is true for individual differences such as varying expertise and role competence. But the differences also apply to other factors, such as social skills, personality and the famous “clinical eye” (see Decision making in the team above). Several senior respondents report that it is sometimes necessary to permanently remove certain individuals from the trauma team because they simply do not fit into the trauma context. Furthermore, disinterest in the trauma situation is something that is frequently mentioned as a reason for not behaving or performing at a desirable level. This may be the case for example when resident surgeons are drafted onto the team as a part of their training. However, as noted in the Variations section, the level of interest for the trauma discipline in the hospital management reportedly varies as well, resulting in fewer professionals interested in trauma gather at sites where trauma is not recognized and prioritized. This affects the performance of the trauma team at a general level.

An issue introduced by several informants is that trauma care is an area which demands very broad expertise, while health care is generally becoming more specialized. Doctors and nurses are encouraged to increase their competence in a narrow field, resulting in, for example, extremely competent vascular surgeons with a limited capability in dealing with other surgical procedures. This, combined with the fact that there are no surgeons exclusively dedicated to trauma surgery in Sweden, means that it may be a challenge to find professionals with expertise broad enough to ideally suit the trauma situation.

Lack of hands-on experience

In the Variations section, it is mentioned that Sweden is a country where the trauma rate is significantly low, both in relation to overall population and even more so geographically, due to the low population density. This results in overall lack of practical experience amongst Swedish trauma professionals. Swedish trauma care has become more centralized in recent years, so patients are treated in the sites having the highest level of resources and competence. This concentration of trauma patients to certain hospitals has resulted in more hands-on practice for trauma professionals at those sites, but informants still believe that they could benefit from even more. The centralization process has probably resulted in hospitals which are more experienced as a system, but spread out on every individual, it is still perceived as not being enough. A general surgeon and team leader says:

“It would surprise me if patients are not suffering, even dying, due to the lack of experience. And experience can only be gotten by exposure, often and a lot of it. And we are not doing enough of that. So this is clearly a problem and a weakness, there is no doubt about that” (R1).

Needless to say, respondents still consider it a very positive thing that the rate of injured people in the country is low. The lack of real-life experience is compensated for, at least to
some extent, by extensive training, simulations and the like. This practice seems to be much appreciated by all team members, but is difficult to organize due to a lack of time and the amount of people involved, and the general opinion is that additional training is preferable.

**IT systems and radiology**

Modern health care is supported by many computerized systems. The most salient one in initial trauma care may be the CT scanner and its supporting systems, but there are also patient monitoring systems and medical records systems. There is a widespread dissatisfaction among professionals interviewed regarding the computer systems in general healthcare. They are considered time consuming, inflexible, illogical, not adapted to the situation and isolated from each other. For example, when discussing the positive aspects of viewing images in the PACS without having to go to the radiology department, an anesthesiologist says:

“That is something that has made our everyday work easier, that we don’t have to run down there. And that is sort of unique when it comes to IT. Almost all new IT solutions has instead cost us time.” (R10).

However, the general impression is that problems and efforts associated with computerized systems are fewer in the initial part of trauma care, compared to other areas of health care, since the team in this phase is not overly dependent on a multitude of systems.

The ability to perform CT patient examinations is considered extremely helpful, not to say crucial, in the trauma context, but there is opportunity for improvement: several respondents believe that the time requirement for the CT procedure can be reduced. The actual scan is quite fast and satisfactory, but the professionals require faster access to the images produced. Images cannot be viewed on the modality stations simultaneously as the scanning is in progress. Furthermore, considerable time is lost, relocating the patient from the TR to the CT scanner. If the CT suite is not adjacent to the trauma room, the patient must be transported to the radiology department. While in the CT suite, it may be an elaborate process moving the patient from the trauma stretcher to the couch of the CT scanner, especially if the patient is in a bad condition and connected to various lines and equipment. A trauma team leader at a hospital were the patient has to be transported to another floor for the CT examination says:

“At Karolinska [university hospital and the largest trauma center in Sweden] the emergency facilities are very homogenously located. Here, it is sort of chaos in regard to that. The helipad is 10 minutes away up and down and this way and that way, and then we have the ED, and then the CT, 10-15 minutes more. You have to bear this in mind, so you don’t send anyone to the CT who is getting worse later. Then you would make a fool of yourself. At Karolinska, I imagine that they dare to send worse patients to the CT” (R4).
Currently, the average time spent in the CT suite is about equal to the time consumed in the trauma room, and many consider the computer tomography to be a time thief. It is sometimes jokingly referred to as “the donut of death”, because of the risk that the patient dies during the examination. However, opinions on this issue differ, and some – usually radiologists – argue that the trauma patient is at risk of dying regardless of the system used to examine him. It might even be advantageous to make a very quick scan of the trauma patient before the clinical examination, to obtain a brief overview of the injuries. This new and progressive approach is currently being explored (Leidner & Beckman, 2007).

Some interviewees also emphasize the stressful work situation for the trauma radiologist. When performing the primary radiological survey of the CT images in the CT suite, other members of the team gather behind the radiologist and may queries and requests for her. A senior anesthesiologist says:

“We [the anesthesiologists] are a part of the decision process. We usually stand behind the wall there. And the radiologist on duty, everyone is rushing the poor guy to review the images as fast as possible, and the surgeons are breathing down his neck and wanna know: ‘where is the blood?’” (R10).

However, the radiologists interviewed do not consider this a big problem, but emphasize that you have to stand up for yourself and what you believe is the best way to review the images, when other members of the team demand certain procedures and answers.

The documentation and medical record systems are frequently criticized. Several respondents state that there is currently no good method to store and retrieve patient and injury information. For example, an orthopedic surgeon (R5) reports that information about a patient’s injuries is split in several locations based on the individual who wrote the records, so in order to obtain certain information, she has to guess who created that particular record.

**Communication, teamwork and information loss**

With all due respect to the problems addressed so far in this section, the most prominent of them all remains: the communication, or the lack of it. Communication difficulties are something that all respondents bring up or acknowledge, and these problems are intertwined with several of the issues above, such as the problem with the varying leadership and the situation for the trauma radiologist.

Communication, the transmission and distribution of information, is something that is crucial to any competent team and/or system (Berko, Wolvin & Wolvin, 2001). To communicate effectively, however, can be difficult, especially in the trauma situation where a fine equilibrium between talking too much and talking too little is the ideal.
Communication problems reportedly exist even in trauma centers where the organization is considered to generally work well.

First, the feedback to the paramedics is insufficient. The communication between the ambulance and the trauma team is asymmetrical, in that the ambulance staff reports all the information about the patient and the injury event known up to that point in time, but they rarely receive any information back about what happens later with the patient, and if they should have done anything differently in their part of the process. Therefore, they are unable to completely evaluate their work. This problem is acknowledged both by paramedics and members of the core trauma team.

In the trauma room the situation is very delicate regarding communication. Many people need to be coordinated, which calls for very strict communication. Ideally it should very quiet in the room, so that everyone present can follow what is happening, the scribe can document the findings of the primary examining doctor and others involved, and the trauma leader can hear and be heard. On the other hand, actually communicating rather than being completely quiet is required if everyone is to understand what is going on. The sum of this equation is that information must be verbally and clearly communicated, but in a strict and orderly way, without any irrelevant interfering information.

In practice, this ideal is rarely followed perfectly. The team members may be chit-chatting and joking (especially when gathering in the TR before the patient arrives), discussing and asking each other questions. The bystanders are doing the same with each other, as well as sometimes conversing about related subjects. There is frequent telephone traffic in the room. Usually one must be fairly close to the stretcher to hear what the core team is saying – when the observations of this research were carried out, details of the dialogue were rarely perceived. But reportedly, the more serious the situation, the less noisy it is in the TR. Ironically, in those situations it can sometimes be too quiet. The team leader is focusing on the complex task at hand, and forgets to communicate. This leads to loss of information sharing in the TR. An anesthesiologist says:

"Half of the crowd in there doesn’t know what the plan of the trauma leader is, for example. That means that half the crowd doesn’t have a clue of what’s going on, [the same] half of the crowd can’t provide any good suggestions. It is a very poor use of resources." (R9).

Hence all members in the team might not be aware of what the strategy or treatment plan is, which hardly is optimal for the performance of the initial trauma care system.

In several trauma centers, the radiologist who is on trauma call is not involved in the care until the patient is transported to the CT suite. Hence, this person is not really a part of the team until it is starting to disband. This means that the radiologist has less detailed information about the patient, his injuries and the situation, than the other team members have, which is not considered ideal.
Respondents also acknowledge communication problems when reporting to each other. This is compared to the children’s game of “Telephone”, where the participants pass on a message by whispering to each other, and in the end it gets distorted and differs significantly from the original content. If not practicing a strict and standardized way of passing on information, this can be the case. An anesthesiologist states:

“There are still problems regarding the communication, especially when reporting. It is difficult to make it work - it’s not unusual that we are coming to the OR to hand over the patient, and they know nothing about him. I’ve called mine [the anesthetists in the OR] and told them a little, and some other guy has called - you know, they have no overall picture, they just get an extremely ill patient on their hands” (R11).

The shorter the information chain is, the fewer problems occur. If the patient, for example, is immediately operated on after the initial surveys, the team leader is usually part of the team in the OR and, therefore, less information is lost. The reporting is more of a problem when it comes to fractures and other injuries which are not immediately fixed; because in such cases the information must be passed on through several persons. The distribution in time might also imply information loss, as data does not stay fresh in the mind and is not all documented. Rounds where trauma patients are discussed, post initial care, are a much appreciated way to learn and share information, but little is documented from these sessions.

To summarize, information is sub-optimally distributed across the initial trauma care system, and this is reported to affect teamwork negatively. Respondents argue that the team being ad hoc, temporarily composed, makes teamwork more difficult. When not knowing the capacity and personality of other team members, it is more difficult to hit the appropriate “level” on which to communicate. Vocabulary can also differ between different specialties. Studies on group performance and effectiveness research suggests that teams with low levels of familiarity are less effective than counterparts where the team is more established (Guzzo & Dickson, 1996)

That failures regarding communication and teamwork are reported as a main problem, is not unique for the trauma teams of this study. In recent years those issues have begun to gain attention. Research suggests that flaws in verbal and written communication between health care workers contribute to the majority of all mistakes that affects patients within health care (Wallin & Thor, 2008; Leonard, Graham & Bonacum, 2004). This will be further discussed in the next chapter.
Recommendations

In this chapter changes that could possibly improve the trauma care will be discussed, based on the results of the research. However, as the main purpose of the thesis has been to supply a foundation for such a discussion, rather than to provide any answers, it is not suggested that the following be an exhaustive report of possible improvements. First, the issue of IT systems supporting trauma care will be discussed; afterwards non-technical improvements are discussed.

Needs and possibilities for IT systems in trauma radiology

Hollnagel & Woods (2005) writes about the accidental user, defined as a person who is forced to use a specific artifact to achieve an end, but who would prefer to do it in a different way if an alternative existed. The artifact – which is often an IT system – hence obstructs the way to the goal for the user. As stated above in Detected problems and difficulties, there is prevailing dissatisfaction with IT systems in health care, and therefore a lot of accidental users can be found in this domain, which should have a monumental negative impact on efficiency and possibly even effectiveness. However, the majority of the respondents’ complaints of IT solutions does not concern the systems used in the initial part of trauma care. The criticism instead focuses on software used in the ICU or ED, systems for medical recordkeeping, and the general communication between different IT systems.

One contributing factor for this may be that not many IT systems are being used in the phase of trauma care that has been a studied, apart for those for radiologic purposes. Hence, there are not as much to complain about. However, on the basis of the results, the most important general requirements for any IT system introduced in trauma care would be the following.

- **Speed** would be the highest priority. The urgency is the main characteristic of the initial trauma care and respondents repeatedly state that to be useful, any system needs to be very quick.
- This also implies that **ease of use** would be more important than advanced functions. A system that requires effort in order to perform a certain action would not be useful in the trauma setting.
- In all situations a system should preferably have an **intuitive interface** – which in Normans (1996) words would be an interface with proper affordances – but this is an extra high priority in the trauma setting, as the members of the team constantly change and many professionals involved do not regularly work with trauma. Therefore, a short learning curve is essential.
- Possible to seamlessly **integrate with existing systems**. To avoid user frustration on this point.

In short, simplicity should be prioritized over complexity. However, designing for simplicity by developing a very clean and non-complex interface may merely hide the complexity of a
system, and therefore decrease system control (Hollnagel & Woods, 2005). The designer of a system in the trauma context must bear this trade-off between simplicity and complexity in mind.

Within the radiology part of the workflow, on which there was a focus on during this research, these requirements are of course valid as well. In terms of needs or preferences, the only aspect that has emerged within this domain during the ethnography is basically faster diagnosis, with maintained or improved exhaustiveness of detected injuries. This could be accomplished in many different ways, from faster hardware and/or software to more efficient organization or systems providing better decision support. Improved decision support may also increase the role of the second system of reasoning – discussed in the Decision making in the team chapter – by providing more explicit parameters. This may to some extent decrease the importance of individual experience in the decision making process.

However, the users appear quite satisfied with the existing radiology systems, with the request for increased speed as an exception. Below, the radiology IT product that initiated this study is presented. This product will serve as a starting point for a discussion of the integration of more efficient IT solutions in the trauma radiology work flow, as no needs for other solutions has emerged during this research.
The Sectra Visualization Table – an example of emerging IT solutions for radiology

The Sectra Visualization Table, in the following abbreviated to SVT, is a multi-touch tool for visualization of and interaction with CT and MRI data.

**FIGURE 12: The visualization table**

The SVT is a combination of a modified version of Sectra PACS and a multi-touch screen solution. It has a 46” display, allowing visualization and direct manipulation of image volumes, primarily 3D reconstructions, with the hands – the user can zoom, pan and rotate the images, as well as apply various filters. Layers of skin and muscle can be removed in order to view the preferred tissue, and sections can be cut through with a virtual knife. The format allows both horizontal and vertical use.

The idea behind the SVT is to reduce the need for invasive surgical procedures, for example within forensics, but Sectra believes it has several other hypothetical advantages compared to traditional radiological work stations which consists of standard computers with mouse and keyboard manipulation. Sectra believes that the format may enhance collaboration, because of the large screen around which a smaller group of professionals can conveniently gather and still be able to interact. The presumed intuitiveness of the touch interface and the large and easily manipulated 3D visualization could also facilitate forming medical conclusions from the image data, according to Sectra.
However, it is not established in which medical domains the SVT could be of use. Earlier thesis work at Sectra suggests that the SVT could be a useful tool in the diagnosis of trauma patients (Nyström, 2011). This was a precursor to this thesis.

During interviews, the concept of the SVT was introduced to all respondents at one point in time or another, but care was taken not to ask leading questions or strongly imply any possible advantages of using the tool, and instead merely describe the device and its existing functions, to allow for accurate exploration of the possible use of the tool.

The SVT concept incorporates two current trends within IT: 3D visualization and multi-touch displays. Exploration of the possibilities of 3D has developed in recent years, due to advances in display technology and computational power. The application of multi-touch tables within healthcare are currently being explored (Piper & Hollan, 2009). This makes the SVT a relevant example from which to discuss IT solutions within trauma radiology.

**Lessons learned from exploring the possibilities of SVT**

Would a tool with all or some of the properties of the SVT be of use in the initial trauma care domain? Three qualities differentiates the SVT from existing systems in the radiological workflow: a) the **format** – the screen is considerably larger than the current work station, and allows multiple users to gather and interact with the system. b) the **multi-touch interface** – directly interacting with images on the screen is very different to manipulation via keyboard and mouse. c) **3D visualization** exists in normal work stations as well, but is quite different to interact with on the large multi-touch display. The utility of these properties within initial trauma care is discussed separately.

**Format**

A bigger display would increase the distributed accessibility of the images, which could be useful since the trauma care system includes several individuals with interest in the images. A general surgeon (R1) suggests that a bigger screen attached to the wall, merely presenting images as they arrive during the CT scan may calm the doctors present.

A large display could facilitate discussions about the image data, by enabling more all professionals included to view and show the images and point at details of interest. However, it is unclear if there is a need for such discussions in the CT suite. The radiologist is the one responsible for interpreting images, and in this phase of the trauma work, there is little interest among the professionals in better understanding or knowing any details about the injuries. Hence communication mainly deals with the possible existence of injuries. There is no time for more extensive discussions, why a large format of a tool showing radiological data might be superfluous. The main goal of the initial trauma radiology is diagnosis rather than image and injury display, and no informants report that there are collaboration difficulties when reviewing the images.
Furthermore, a tool with the magnitude of the SVT would be too large and unwieldy, at least for horizontal use, for the facilities where the work stations are placed today. It would be difficult or nearly impossible for the physicians to gather around it conveniently, due to shortage of space. These areas could of course be rebuilt or reorganized, but the limited availability of room is something that at the moment must be considered when developing any hardware for the trauma domain. Small and flexible tools are preferable.

**Multi-touch interface**

A tool for visualization and manipulation of radiological images with a multi-touch interface should have better affordances than an ordinary work station, as the interface more closely resembles manipulation of physical objects. Touch screen interfaces in smart phones for example, are a huge commercial success and often considered more intuitive than previous technologies. Studies show that touch interaction is significantly more efficient than the traditional mouse in certain types of tasks (Kin, Agrawala & DeRose, 2009). This could be very welcome in the trauma context where efficiency is such an important quality.

If cognition is as embodied as distributed cognition (see *Theoretical framework*) suggests, perhaps the tighter coupling between the body of the user and the objects to be manipulated, that touch interfaces supply, could facilitate the trauma professionals’ cognition. Interfaces where abstract objects, e.g. image data, are manipulated similarly to physical objects enable physicians to organize their environment to decrease cognitive load just as Kirsh (1995) suggests.

However, it is not apparent how a touch interface could fit in the existing tasks more concretely. The actual image manipulation in the initial trauma care is infrequent. As earlier described, radiologists manly iteratively scroll through stacks of images to detect deviations from the norm, a very simple form of manipulation, where the positive effects of multi-touch input is probably limited. Also, no respondents report that there are any difficulties or obstacles obtaining the information or performing manipulation of the images with the current systems.

**3D visualization**

Theoretically, a tool facilitating the visualization of 3D images may indeed improve the interaction with medical images. As early as 1971, Shepard & Metzler (1971) in a classic experiment showed that we seem to have mental representations of physical 3D objects in the world, i.e. “images in our heads”, that behave much like the physical objects they mirror. It was discovered that manipulation of those representations takes time and effort. When subjects compared pictures of two items, where one was a rotated version of the other, and deciding if the objects were the copies or different, the response time was linear with the rotation angle between the two objects. This suggests that an effective 3D visualization would facilitate the understanding of medical image volumes for physicians.
Since we perceive the physical world in three dimensions, it is tempting to jump to the conclusion that the ultimate representation of a real world object would be a 3D visualization. But this is not always the case. For example, consider the map – this is an artifact deliberately constructed to describe what it represents in a simplified and symbolized manner as well as from another perspective than we usually perceive the original. For the user, a representation that is more similar to the three dimensional reality would not facilitate the task of orientation.

The radiological workflow within the initial trauma system is a similar situation. For a layperson a 3D reconstruction of CT data is much more comprehensible than the crude 2D slices in grayscale of the same anatomical area (see figure 12). But the trauma radiologists see the images very differently. For them, rapidly and systematically scrolling through the stacks of 2D slices in order to detect small abnormalities is considered efficient and effective. For them, the 3D model may probably be confusing rather than helpful, as the extra dimension adds complexity to the image while at the same time obscuring information by disabling the sequential review procedure. The goal for the radiologist is not to understand what the injury looks like, but rather to detect it. This is critical for the possibility of implementing any tool with 3D visualization as its primary function, since the radiologist, as a rule, is the one in charge in the CT suite; while the others are waiting for an opinion or asking her questions.

The general surgeons are typically not interested in better knowing the nature of the injuries before making the incision. They need to know if intervening surgery is plausible, and the area where the injury is detected, but the general opinion is that sufficient information about the injuries is obtained by actually performing the surgery. The situation where a 3D visualization tool would provide an advantage does not really exist. If there is a very urgent need for an operative intervention, surgeons do not find value in spending time exploring 3D reconstructions and discussing surgical procedures in the CT suite, they just want to
make the intervention. On the other hand, if the trauma case in question is not in immediate need of surgery, the images are still not being reviewed in detail in the CT suite, but by the radiologist at the radiology department, who is not interested in 3D imaging.

Furthermore, 3D reconstruction often adds time to the procedure. Since speed is the overriding requirement when it comes to the primary review of the images, to be useful, any tool featuring 3D visualization must be as fast as the current solution – which is already considered too slow by some. The team members do not request better imaging or visualization, they ask for faster systems.

In conclusion, there seems to be little need for 3D imaging tools within the early phase of trauma care. There might be an exception for neurosurgeons, who by other respondents are reported to be more interested in exploring 3D volumes, as they cannot employ the same “open up and look” principle as the general surgeons. Unfortunately, no neurosurgeons have participated in this research, and therefore no conclusions on the matter can be made. 3D imaging tools could possibly also be useful in some cases that differ from the average trauma patient, for example in being more complicated or by involving severe pelvic fractures. 3D is generally considered useful when it comes to fractures, and injuries of the pelvis are among the few fractures that often need to be urgently fixed.

Although it is outside the scope of this study, the conclusions suggest that 3D visualization could be useful in orthopedic and plastic surgery of trauma patients that is usually undertaken several hours or even days after the traumatic event. In these cases it is much more important to understand the exact nature and structure of the injury before performing the operation. 3D reconstructions of image data can be used to get a comprehensible overview of the injuries. Several respondents claim that 3D visualization is very valuable for facial fractures and surgery of the ears and jaw, and all orthopedic surgeons consulted in this study report that they frequently use 3D reconstructions in their work, especially for pelvic fractures and fractures close to a joint. One orthopedic surgeon states:

“The best orthopedic surgeons that I’ve met are the kind that is sitting for hours rotating an image before they perform the operation. So they have the complete fracture memorized in their head when operating.” (R5).

The 3D imaging could possibly facilitate the process of understanding the orthopedic injury in full, and should definitely reduce the cognitive load of the orthopedic surgeon. In a recent study of the visualization table among orthopedic surgeons at a Swedish university hospital, the declared that the tool would indeed be valuable in their clinical work (Lundström, unpubl.).
To summarize, multi-touch interfaces could add intuitiveness and facilitate interaction with IT systems in trauma radiology, while the format of such a tool has to be carefully adapted to fit the cramped and crowded environment. 3D visualization does not seem to benefit tasks in the current initial trauma workflow, other than in exceptional cases. Overall, no general immediate need for changes or improvements system-wise in trauma radiology is found, at least radiology is not the area where respondents identify problems.

The few radiologic issues that are brought up focus on the ability to logistically perform the CT scan easier and faster, and have more to do with hardware than software. As CT images are merely snapshots in time and the state of trauma patients may change rapidly, it is sometimes desirable to easily re-scan the patient, although the risk of increased radiation exposure must be considered. Strategies where trauma patients go through a simpler low-dose CT examination before the primary survey is conducted, are currently being evaluated at Swedish and foreign hospitals (R7; Leidner & Beckman, 2007). This approach provides immediate radiological information which serves as a basis for diagnosis and triage.

Dealing with the problems – non-technical areas of improvement

“If you want to make a big contribution to health care, you should reform these areas [communication and teamwork], because then you would get - you would get huge results, more than any other intervention regarding science, pharmaceuticals, anything would bring. By making these interventions regarding communication and collaboration” [R9]

As previously stated in Detected problems and difficulties, the main problems detected in the trauma care chain by this research are not technical but organizational and/or human oriented, as the quotation in the beginning of this section illustrates. This does not mean that these difficulties cannot be resolved, but there may be the need of a different approach.

There seems to exist a prevailing belief in individuality in health care, despite the fact that many health care professionals work in teams or groups. The trauma teamwork reportedly varies depending on the individuals involved, leadership skill is considered to be an intrinsic trait, and communication and collaboration difficulties are said to stem from the fact that the team does not know each other and that some people just do not work well together. There might be a lot of truth in this, but there are ways to address these challenges.

According to research on group dynamics teamwork, leadership skills and effective communication is something that can be learned and practiced (Forsyth, 2006). There are strategies for effectively leading a group while yet being perceptive to input, as well as maximizing the contribution as a following team participant. There are methods for structured communication and coordination of work in stressful and critical situations. In aviation - a field that is often compared to trauma, intensive and surgical care due to teams’ similarities of working in pressing high-risk situations (Sexton, Thomas and Helmreich, 2000) – such strategies are already applied. An example is CRM, Crew Resource
Management, a training system focusing on communication, leadership and decision making. CRM was developed as a safety-training program by the aviation industry, as a response to research concluding that accidents and errors in aviation were frequently related to failures in communication and leadership, rather than flying skills or aircraft malfunctions (Helmreich, Merritt & Wilhelm, 1999). Since then, CRM has been applied in fields where teams work under similar conditions and research suggest that health care could learn from the aviation industry (Eisen & Savel, 2009). Studies of surgeons and air medical professionals also shows that CRM training does indeed increase communication in emergency situations (Cole & Crichton, 2006).

The CRM approach emphasizes the team as a system, rather than focusing on individual performance, and hence corresponds with CSE and distributed cognition. That individuals are to blame or thank for a certain outcome is an outdated approach within behavioral science and human factors engineering, but seems alive and well within the health care sector, where the highly competent surgeon often is considered a hero, incapable of making mistakes (Sexton et al., 2000). According to a respondent – (R9), a physician with experience of trauma team work, also working with simulator based training for health care – approaches focusing on “soft” factors like communication and teamwork are still in their infancy in health care, although definitely on the rise. Health care team members do work as a group, but many have no understanding of what teamwork actually implies – just performing procedures within a team does not mean that the teamwork, i.e. coordination, communication and management, is effective.

To rely on the strength of individuals hardly builds a safe and robust system. Hence, if team members learn teamwork strategies and practice those, in simulator settings for instance, much would probably be gained, and some of the problems regarding leadership, dependency on individual traits and communication skills may disappear. These ideas are already gaining ground. The trauma teams are having training sessions, including advanced simulations with dolls mimicking injured patients, where they can practice teamwork and communication.

In the late 1990’s, SBAR, a systematized way of communication which was originally developed by the US Navy, was introduced in health care, but it has not gained popularity in Sweden until lately. 2008 the World Health Organization developed a Safe Surgery Checklist, identifying three phases of the operation procedure (WHO, 2011). Before every phase is initiated, a checklist coordinator confirms that the team has completed the tasks specified on the list, to ensure nothing was forgotten or missed. These reconciliations correspond to a briefing/introduction, time-out and debriefing. A local adaption of this checklist for the trauma context is now being piloted at one of the trauma centers in this study. However, during observations, this checklist was not always properly followed. Specifically the final debriefing was often skipped.
Training and simulation - something that the trauma professionals want more of, as noted above in the *Detected problems and difficulties* chapter – would probably not only improve communication, teamwork and the reliability of the general team performance, but also aid decision making. Improved communication implies a better information flow, contributing to a better decision basis. The added experience, even though artificial, could also be helpful when judging a real situation, especially given how important experience and “gut feeling” seems to be for the decisions in the trauma context.

In conclusion, according to the findings of this research, employing deliberate strategies for teamwork and communication training would probably produce the biggest improvement in the initial trauma care system.
Notes on method issues and further research

Ideally, an ethnographic approach to exploring such a complex domain as trauma care should involve a higher ratio of field observations, to supplement interviews, than this study entails. The value of experiencing a domain with one’s own eyes cannot be overestimated. However, in order to do this, a significant amount of unproductive time would need to be spent in the field, as patients do not arrive according to a schedule. Also, busier trauma centers than the ones in this study could be chosen. As mentioned, Sweden is a country where the trauma frequency is relatively low, hitting a statistically all-time low each year during January to March, the exact time period when the data collection of the study was conducted. Furthermore, more than one researcher during the observations is recommended, as the amount of people involved in the trauma system makes it difficult to grasp all activity.

To obtain as much information for the study as possible, several of the chosen interviewees were members of the trauma committee and/or responsible for different parts of the trauma care chain at the hospital in question. Consequently, a majority of the interviewees had a specific interest in trauma care, which may have affected the generalizability of the results. On the other hand, many professionals working with trauma do have a special interest in that field – or else they would have chosen to work within another domain, so the sample could be quite representative after all.

However, since a majority of the informants in this study have been fairly experienced or at least have an interest in and knowledge of trauma, the conclusions regarding the (lack of) need for additional or altered IT systems supporting work may be slightly misleading. It could well be the case that more junior or inexperienced surgeons and other team members might appreciate a tool like, for example, the SVT. Since experience is considered such a crucial part of competence in the trauma context, less experienced individuals may have other ways of working and other requests for decision support. A better visualization of images could possibly be helpful for trauma professionals with less hands-on practice.

Furthermore, I believe that an artifact similar to the SVT, combining the three properties discussed in the previous chapter and promoting large, comprehensible and easily interactable visualization of volumetric data, could possibly be indirectly valuable for the initial trauma system, by being used for educational purposes. Many of the respondents stress that 3D visualization is not used when it comes to diagnosis, but that it is a great way of showing pathology in a lucid and comprehensible way. This combined with the ability to easily interact with and communicate about the images would probably make the SVT or a similar tool ideal for educating and training medical school students, interns and residents, as well as situations where physicians need to discuss and show images, such as rounds, follow-up of complex cases, and M&M conferences. A large-screen tool deliberately designed for 3D visualization, especially with a touch interface, would enable a more
explorative approach of image viewing and could possibly ensure that everyone involved has similar mental representations of the situation.

The validity of the above requires further research on the subject, as it is outside the scope of this study. Such research could also focus on the aspect of the trauma care flow that has not been included here, i.e. what happens after the initial attendance. The complete trauma care chain can be long and complex, as multi-injured patients require a variety of treatment, as well as rehabilitation (R4). Subsequent parts of the flow do not appear as structured and systematic as the initial attendance, and definitely involves even more people and more technology. Therefore, more research in these areas would be both interesting and beneficial.
Conclusions

Trauma care has been explored with ethnographic methods and analyzed according to the cognitive scientific perspectives of distributed cognition and cognitive systems engineering.

The trauma team and any other professionals, artifacts, and structures involved in the urgent phase of trauma care, have been described as the initial trauma care system. This is a system functioning under demanding circumstances: there is extreme time pressure, risks are high, the involved professionals may not know each other and information about the complex environment is incomplete.

The initial trauma system follows many standardized procedures to overcome the complexity of the situation. Previous experience of clinical trauma work is reported to significantly facilitate and improve work and role competence. Effective leadership is also considered very important for the team performance.

Despite clearly defined roles, individuals matter. Problems and difficulties in the work of the initial trauma care system are often the result of poor communication and poor teamwork between some or all of the team members. In this thesis, the possibility of developing skills in communication, teamwork and leadership, through education and training, has been discussed.

The responsibility for decision making in the initial trauma care system relies first and foremost on the trauma team leader. However, it is usually a somewhat socially distributed process. CT imaging provide good decision support and professionals seem fairly satisfied with the existing radiological systems, with the exception of several respondents wishing for a more rapid CT process. 3D visualization is probably not useful in the current workflow for the initial trauma care system, but may provide advantages in further trauma patient treatment. A tool combining 3D visualization with a large multi-touch screen may also be useful for educational purposes – teaching, learning, and understanding pathology.
References


Appendix A: Abbreviations and explanations

In this section information on abbreviations and concepts used in the thesis can be found.

Abbreviations

ATLS – Advanced Trauma Life Support
  A – Airways
  B – Breathing
  C – Circulation
  D – Disability
  E – Exposure/Environment
CRM – Crew Resource Management
CSE – Cognitive Systems Engineering
CT – (imaging technique) Computed Tomography
ED – Emergency Department
GT – Grounded Theory
ICU – Intensive Care Unit
JCS – Joint Cognitive Systems
FAST – Focused Assessment with Sonography for Trauma.
MRI – (imaging technique) Medical Resonance Imaging
OR – Operating Room
PACS – Picture Archiving and Communication System
RIS – Radiology Information System
SBAR (communication technique) – Situation, Background, Assessment, Recommendation
TR – Trauma Room
WHO – World Health Organization

Explanations

Anesthesiologist – physician with doctor specialty in anesthesia, often works peri-operative or in the ICU.
Artifact – something created by humans, usually for a specific purpose.
Cervical spine – the vertebrae of the neck.
General surgeon – surgeon specialized in the abdominal organs.
Hemodynamically stable – with stable heart rate, sufficient oxygenation and acceptable blood pressure.
Intubation – formally tracheal intubation, the placement of a flexible plastic tube into the windpipe to facilitate ventilation of the lungs and to prevent the possibility of airway obstruction.
Mortality & Morbidity conference, also M&M conference – reviews of possible mistakes occurring during the care of patients.
Orthopedic Surgeon – surgeon specialized in the musculoskeletal system, such as bones, joints and muscles.

Pericardium – the membrane surrounding the cavity around the heart.

Radiologist – physician specialized in obtaining and interpreting medical images

Thorax – the chest.

Triage – the process of determining the priority of patients’ treatments based on the severity of their condition.

Vital signs – certain basic physiologic measures used in the initial clinical assessment of a patient during a physician’s examination, in order to assess the most basic body functions. Includes body temperature, blood pressure, pulse and respiratory rate.
Appendix B: List of interviewees

R1 – general surgeon and trauma team leader
R2 – general surgeon and trauma team leader
R3 – general surgeon and trauma team leader
R4 – orthopedic surgeon and trauma team leader
R5 – orthopedic surgeon and former trauma team leader

R6 – radiologist
R7 – radiologist
R8 – radiologist

R9 – anesthesiologist
R10 – anesthesiologist
R11 – anesthesiologist
R12 – anesthesiologist
R13 – anesthesiologist
R14 – anesthesiologist

R15 – emergency physician
R16 – emergency physician
R17 – emergency physician resident

R18 – reg. nurse with nurse responsibility for trauma
R19 – reg. nurse with specialty in radiology
R20 – reg. nurse with nurse responsibility for trauma
R21 – reg. nurse and former paramedic

Total number of doctors: 17
Total number of reg. nurses: 4