Paula Puhilas

SITUATION AWARENESS IN CLINICAL DECISION SUPPORT SYSTEM

CASE TRAUMA TEAM

JYVÄSKYLÄN YLIOPISTO
TIETOJENKÄSITTELYTIETEIDEN LAITOS
2015

ABSTRACT

Puhilas, Paula
Situation awareness in clinical decision support system: Case Trauma Team
Jyväskylä: University of Jyväskylä, 2015, 70 p.
Information Systems, Master's Thesis
Supervisors: Tuunanen Tuure; Saariluoma Pertti

At this moment there is no electronic clinical decision support system in use at the case site. Study aimed to find out how a clinical decision support system can support situation awareness in trauma team's decision making in the Central Finland Central Hospital. Trauma team is a multidisciplinary team performing trauma resuscitation in an emergency department. Better situation awareness results in better decision making. Research focus was set on finding out what information the trauma team needs to be aware of to gain and maintain situation awareness.

An interpretive qualitative case study is performed to construct a model, which answers the research question. Eight trauma team exercises were video recorded, observed and debriefing sessions were transcribed to form a basis for interview questions. 15 trauma team members including 5 surgeons, 4 anaesthesiologists, 3 anaesthesia nurses and 3 trauma nurses were semi-structurally interviewed. Two matrixes were developed from the information elements mentioned in the interviews. A situation awareness model was further developed to support trauma team activities based on the matrixes, goals and decisions mentioned in the interviews.

Trauma team's goal is to keep the patient alive. Ensuring breathing and blood circulation and monitoring vital signs are decisions associated with this goal. Information for this decisions are basic illnesses and medication, injury energy, injuries, information about abnormalities (breathing sounds), oxygen saturation, blood pressure, heart rate, consciousness and looks. The model presents these preliminary requirements for decision support in a car crash situation. The model can be used to derive more profound requirements analysis for an electronic clinical decision support system.

Keywords: situation awareness, clinical decision support, CDSS, trauma team, decision making

TIIVISTELMÄ

Puhilas, Paula
Tilannetietoisuus kliinisen päätöksenteontukijärjestelmissä: traumatiimi case-tutkimus
Jyväskylä: Jyväskylän yliopisto, 2015, 70 s.
Tietojärjestelmätiede, pro gradu
Ohjaajat: Tuunanen Tuure; Saariluoma Pertti

Tällä hetkellä tutkimuskohteessa ei ole käytössä elektronista päätöksentukijärjestelmää. Tutkimuksen tarkoituksena oli selvittää, miten kliininen päätöksentukijärjestelmä voi auttaa tilannetietoisuuden muodostumista päätöksenteon tueksi traumatiimin toiminnassa Keski-Suomen keskussairaalassa. Traumatiimi on moniammatillinen tiimi, joka hoitaa loukkaantuneita potilaita ensiavussa. Parempi tilannetietoisuus johtaa parempiin päätöksiin. Tutkimuksen fokuksena on selvittää, mitä tietoa traumatiimiläiset tarvitsevat tilannetietoisuuden muodostamiseksi ja ylläpitämiseksi.

Tutkimuksen menetelmänä on tulkitseva kvalitatiivinen case-tutkimus, jossa tuotetaan malli vastaamaan tutkimuskysymykseen. Traumatiimin harjoituksia kuvattiin ja havainnoitiin 8 kappaletta. Lisäksi harjoitusten palautetilaisuudet litteroitiin haastattelukysymysten pohjaksi. 15 traumatiimin jäsentä haastateltiin yksilöittäin puolistrukturoidusti. Haastateltavat jakautuivat viiteen kirurgiin, neljään anestesialääkäriin, kolmeen kiertohoitajaan ja kolmeen traumahoitajaan. Haastattelut litteroitiin ja analysoitiin. Haastatteluissa mainittujen tietoelementtien pohjalta koottiin kaksi matriisia, joita käytettiin tilannetietoisuuden mallin jatkokehittämiseen haastattelussa esille tulleiden tavoitteiden ja päätösten kera.

Traumatiimin tavoite on pitää potilas hengissä. Hengityksen ja verenkierron turvaaminen sekä vitaalien monitorointi ovat päätöksiä, jotka liittyvät tähän tavoitteeseen. Näihin päätöksiin tarvittavat tietoelementit ovat perussairaudet ja lääkitykset, vammaenergia, vammat, tieto poikkeavuuksista (hengitysäänet), happisaturaatioa, verenpaine, sydämen syke, tajunta ja ulkonäkö. Edelleen kehitetystä tilannetietoisuuden mallista nähdään alustavia vaatimuksia, joita tarvitaan päätöksenteon tukemisessa autokolaritilanteessa. Mallia voidaan hyödyntää syvällisemmän elektronisen kliinisen päätöksentukijärjestelmän vaatimusmäärittelyn tekemisessä.

Asiasanat: tilannekuva, päätöksentukijärjestelmät, traumatiimi, päätöksenteko

PREFACE

I want to thank my supervisors Professor Tuure Tuunanen and Professor Pertti Saariluoma for their advice and guidance. Thank you for your support Teuvo Antikainen, M.D., Ph.D., Surgeon, Central Finland Health Care District, Seppo Lauritsalo, Anaesthesiologist, Central Finland Health Care District, Mikko Lintu, Chief Physician of Ambulance Service, Central Finland Health Care District and Jukka-Pekka Mecklin, M.D., Ph.D., Professor of General Surgery, Central Finland Health Care District, University of Eastern Finland. Thank you other employees of Central Finland Health Care District for cooperation. Family and friends, thank you for your patience and support.

FIGURES

TABLES

TABLE OF CONTENTS

1 INTRODUCTION

Information technology is everywhere. In a health care environment the information technology is essential part of procedures when treating a patient. For example information about the patient is saved to and retrieved from an electronic health record when visiting a physician. There is a massive amount of electronic data being produced in the health care. In addition, it is scattered in various formats in different systems. There can be images from computerized tomography, structured data from laboratory results or unstructured data from the physician visit. When there is a situation requiring fast decisions, there is not time to search for the information about the patient from different systems. Emergency departments are said to be a good target for randomized controlled trials as they are areas of high impact decision making (Mickan, Atherton, Roberts, Heneghan & Tilson, 2014). A trauma resuscitation is a situation like that.

In the trauma resuscitation a patient needs immediate treatment. A trauma team is a multiprofessional team, which is working at the trauma resuscitation. There can be multiple trauma resuscitations happening at the same time at the same room. This results in noise from equipment and people. Gathering important information to support decision making can be challenging in a situation like that. This is a challenge especially to a trauma team leader. The leader is responsible for coordinating treatments for the patients (Trauma.org, n.d.). There is a need for a system that supports decision making at the trauma resuscitation especially in a multiple patient situation. The trauma team needs to act as a team for resuscitation processes to go smoothly. Therefore it is important to support core members of the trauma team with their individual information needs and decision making in addition to supporting the trauma team leader.

Situation awareness is a term describing what the individual needs to be aware of in a certain situation. Situation awareness is a basis for decision making and an important factor of action. Therefore it is linked to performance and limitations in SA may result in errors. (Klein 2000, 45.) Studying situation awareness in a trauma resuscitation situation gives information about information needs and decision making of the trauma team members.

1.1 Research Objective and Question

The objective of this thesis is to discover preliminary requirements for an electronic clinical decision support system, which can help decision making by providing situation awareness. The research question for this thesis is:

How situation awareness supports trauma team's decision making in Central Finland Central Hospital?

A qualitative case study is performed to construct a model, which can be used to answer the research question and provide preliminary requirements for an electronic clinical decision support system.

There are many kinds of clinical decision support systems (CDSS) developed and studies on their effects on physicians' performance are done. Wright et al. (2009, 637) mention for example drug-interaction checking and preventive care reminders as different clinical decision support systems. Only one system developed for supporting trauma team's decision making was found. Fitzgerald et al. (2008) have developed a TR&R system and it will be later discussed in more detail.

The theory of situation awareness has been studied in healthcare settings. Research focus has been on operating rooms or work of anaesthesiologists. A situation awareness model for anaesthesia has been developed by Schulz, Endsley, Kochs, Gelb & Wagner (2013) and that model is further developed based on findings of this thesis. This is to provide a lens for future clinical decision support system developers to trauma team activities and how to best support their situation awareness. For supporting trauma team's situation awareness there are two systems in prototype testing phase. Sarcevic and her research team (including Kusunoki and Zhang) have developed an information display (Kusunoki 2014). Yngling and Nilsson with their team have developed a system for remote trauma team expert to take part in patient treatments (Nilsson 2014). These systems are later discussed in detail with describing their studies conducted on decision making and information needs of trauma teams.

Research was done in two phases. First trauma team exercise video recordings were observed to get an idea of the procedures and activities. Second, 15 trauma team members were interviewed. Interviewees included five surgeons, four anaesthesiologists, three anaesthesia nurses and three trauma nurses. Interviews were semi-structured and lasted approximately 30 minutes. A car crash scenario was told at the beginning of the interview and it was used as a basis for questioning. Results were used to derive a situation awareness model for trauma team. This model can be used as a basis for studying end user requirements for a clinical decision support system.

1.2 Thesis Outline

The first chapter is introduction to the thesis topic identifying the motivation for the research. Research question and other similar studies are shortly presented to show need for this study. Thesis outline is also presented. The second chapter has an information technology aspect. Decision support systems are briefly described. Next clinical decision support (CDS) systems are explained with three historical examples and three systems, which are in use today. Next mobile CDS systems are briefly discussed because they present the future of decision support. The second chapter ends with describing challenges in CDS systems. Situation awareness theory is topic of the chapter three. Situation awareness theory is explained. Team situation awareness, situation awareness measures and challenges in medical domain are discussed. In the final section two systems supporting situation awareness in trauma resuscitation are introduced. Methods used are described in chapter four and chapter five tells the results. Information flow during trauma resuscitation, information needs and main goals of trauma team members, trauma team decision making points and challenges in current IT are presented with interview quotations. Chapter six concludes this study.

2 IT HELPING CLINICAL DECISION MAKING

Information technology can help clinical decision making. Increasing quality of care, saving money and decreasing errors are reasons for using technology in healthcare (Militello et al., 2013). There are studies where Health Information Technology is found to have positive impact (Buntin, Burke, Hoaglin & Blumenthal, 2011). Chaudhry et al. (2006) state that Health Information Technology decreases medication errors and increases adherence to guidelines, and enhancing disease surveillance mostly relating to primary and secondary preventive care.

Clinicians need information to make decisions. Too much information can cause more harm than good if cognitive load overloads making information processing too slow. More data does not mean more information. There is a massive amount of data being produced in health care. Figure 1 shows that when trying to find the needed information from the data the information needs to be integrated to the data. When sorting the data produced to find the information needed the sorted bits need to be processed to form the information. Better solutions are needed to narrow this gap. Computers can be used to process the data into relevant information and reducing cognitive load. Erroneous data can have significant negative results for patient care so validation of data needs to be a major concern. (Endsley & Jones, 2012, 4.)

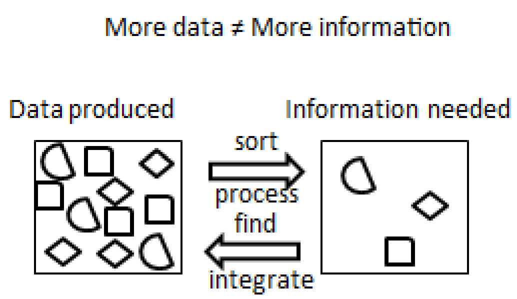

FIGURE 1 The information gap (Endsley & Jones, 2012, 4)

In this second chapter first decision support systems are briefly described. Next clinical decision support (CDS) systems are explained with three historical examples and three systems, which are in use today. Next mobile CDS systems are discussed because they present the future of decision support. The second chapter ends with describing challenges in CDS systems.

2.1 Decision Support Systems

The decision support systems (DSS) can be used to facilitate structured, semi-structured and unstructured decisions. In the structured decision making DSS can understand stable relationships and large number of parameters. In the semi-structured and unstructured decision making DSSs understand large amounts of parameters but also try to alleviate unknown parameters and relationships. Shim et al. (2002, 111) have described decision support systems (DSS) to be "computer technology solutions that can be used to support complex decision making and problem solving." (Hosack, Hall, Paradice & Courtney, 2012, 316.)

In the 1970's the computer-aided decision making began to develop. At that time minicomputers had emerged after large and expensive mainframes which had been in use from the 1960's. In 80's DSS researchers tried to help managers to make decisions as computer science tried to build expert systems to replace managers as decision makers. (Hosack et al., 2012, 317, 319.)

The decision support systems have been successful over four decades. There have been some failures. Hosack et al. (2012, 321) bring up Arnott & Dodson (2008) as they present poor design, lack of shareholder involvement, or poor implementation to be the reasons for failures. They conclude that no matter how good a system, a poor managerial decision making can undermine it. Today we have better and faster technology. In the future technology evolves and it will be even faster. Nowadays we also have larger amount of data to process and decisions should be done in minutes or seconds instead of weeks or days. Amount of data will increase as more and more applications gather information from the surrounding environment. (Hosack et al., 2012, 321-322.)

2.2 Clinical Decision Support Systems

The clinical decision support systems are systems, which help clinicians to make decisions for treating a patient by giving recommendations. Clinical decision support (CDS) is widely used through computer-based systems but also other media like paper can be used to deliver needed information. Adverse drug event detection, drug-interaction checking and preventive care reminders are CDS systems commonly in use. (Wright et al., 2009, 637.)

Moja et al. (2014) summarize characteristics for a clinical decision support system. Characteristics presented in table 1 include implementation strategy, information, format, target, overall goals, time and persons who use it. There are three implementation strategies. Channel is electronic-based. Sharing types are local application, networked or web applications. Computational architecture includes for example CDS system built into local electronic health record or clouding system. Information nature is knowledge-based. There are many information providers including international publisher or governmental agency. The system can use different formats, for example reminders or dashboards, for presenting information. Target settings are primary, secondary or tertiary and target expertise includes diagnosis, planning and implementing treatment among others. Goals of the system are improvement in efficiency, early identifying of diseases, diagnosis accuracy, protocol adherence and preventing adverse drug events. Time of using the system can be at any time or before patient encouter, at the point of care or after the patient encounter. Automatic or on demand are ways for presentation time. Users of the system are physicians, nurses or allied health professionals. These characteristics give guidelines for designing a clinical decision support system.

TABLE 1 CDS system characteristics (Moja et al., 2014, e13).

Implemention strategy	
Channel	Electronic-based
Sharing	Local application, networked or Web applications
Type of device	Local personal computer or handheld device
Computational architecture	CDSS built into local electronic health record, knowledge available from central repository, entire system housed outside local site, clouding system
Information	
Nature	Knowledge-based
Provider	Contents provided by national or international publisher, professional society, health care organization or governmental agency
Evidence-based medicine methodology	General references, specific guidelines for a given clinical condition, suggestions considering a patient's unique clinical data, list of possible diagnoses, preventive care reminders or drug interaction alerts
Format: delivery format	Messages, reminders, prompts, alerts, algorithms, recommendations, rules, order sets, warnings data reports and dashboards

(continues)

Table 5 (continues)

Target	
Targeted setting	Primary, secondary or tertiary
Target expertise	Preventive care Diagnosis Planning or implementing treatment Follow-up management Hospital, provider efficiency Cost reductions and improved patient convenience
Overall goals	Improved overall efficiency, early disease identification, accurate diagnosis, adherence to protocols or prevention of adverse drug events
Time	
Timing	Immediately at the point of care, before patient encounter, after the patient encounter or at any time
Time of presentation	Automatic (key issues: autonomy, timing and user control over response) On demand (key issues: ease of access, speed, autonomy and user control over response)
Person: health professional	Physicians, nurses or allied health professionals

Clinical decision support systems have been seen to improve healthcare when providing aid to practitioners in treating a patient if accurate information is available to clinicians at the right time, context and format. Recently CDSSs have been recognized to help in reducing complexity and costs, which have increased significantly and providing higher care quality and efficiency. Very often decision support is integrated to an electronic patient record. (Duodecim Medical Publications Ltd., 2012, 4, Musen, Middleton & Greenes, 2014, 646.) Sirajuddin et al. (2012, 3) present The CDS Five Rights, which are the right information, to the right person, at the right time, in the right format and through the right channel, to help in making sustainable improvements to the clinical decision. The CDS Five Rights include earlier mentioned right time and format but not right context. Right context is important part of designing effective in addition to the right time and the right context because user-friendly systems because information needs change according to domain.

Several literature reviews have been made from CDSS trials and their impact on improving physician performance. Some impact is detected from the studies. In their decision support systems literature review from 1966 to 2003 Kawamoto, Houlihan, Balas & Lobach (2005) found systems to improve clinical practice in 68% of trials. Four features were presented as important for improvement: decision support as part of workflow, recommendation rather than assessments, decision support at the time and place of decision making and computer based decision support (Kawamoto et al., 2005). These are in line with previously mentioned demands for right information at the right context at the right time to right person in right format. Controlled CDSS trials were studied by Hunt, Haynes, Hanna & Smith (1998) covering years 1974-1992 and as a conclusion CDS systems were found to improve clinical performance in 66 % of studied cases and in other aspects of medical care like drug dosing but not in diagnosis. Garg et al. (2005) found CDS systems to improve practitioner performance in their review of controlled trials between 1998 and September 2004. Jaspers, Smeulers, Vermeulen & Peute (2011) did a literature review of CDS systems' impact on practitioner performance and findings suggest significant evidence of CDSS positively impacting performance especially with drug ordering and reminder systems in preventive care in studies between 1994-2009. Health information technology articles published in January 2010 to August 2013 were studied by Jones, Rudin, Perry& Shekelle (2014) and they found strong evidence to support use of clinical decision support as they improve quality, safety and efficiency. There is an increase of CDSSs impact on physician performance over the years. Research results are positive but there is still a need for an improvement. This is shown by the earlier mentioned percentages, Kawamoto et al. stated 68 % and Hunt et al. stated 66 %. So there are two studies where more than 30 per cent of the cases improvement was not detected.

Some systematic literature reviews were found about effectiveness of electronic decision support in ambulatory care settings. In their study Heselmans, Van de Velde, Donceel, Aertgeerts & Ramaekers (2009) found little evidence for the effectiveness of these systems. Romano & Stafford (2011) had results, which indicate no consistent association to quality. A moderate improvement on morbidity was found on Moja et al (2014) but no effect on mortality was discovered. Fitzgerald et al. (2011) found computer-assisted decision support to improve protocol compliance and reduce errors and morbidity in trauma resuscitation at level 1 adult trauma center. Mentioned results indicate that electronic decision support has some impact on effectiveness or quality in ambulatory care settings.

2.3 Information Technology Aspect of CDSSs

Using the information technology as an aid in decision making has its own restrictions. Paper is found to be better solution over Personal Digital Assistant (PDA) because it does not compete for attention, patient is more aware of physicians activities through non-verbal activities and there is negative attitudes towards PDA because it is not familiar. (Alsos, 2010.) To get physician use decision support systems usefulness, facilitating conditions, ease of use and trust in knowledge base need to be addressed (Shibl, Lawley & Debuse, 2012). Kortteisto (2014) studied in her doctoral thesis primary care clinical decision support system integration to electronic health record system called an advising patient record. After one year study period use of the system was modest. Physicians found it helpful but triggers were criticized. Good usability, content trustworthy and usefulness were found to improve perceived usefulness. Usability and trust in knowledge base are major issues for users to adopt the system. (Kortteisto, 2014.)

When building a decision support system a reasoning system is important. There are different strategies to reasoning. Modern systems typically use Bayesian reasoning, production rules, medical logic modules, knowledge bases consisting of clinicians' orders. There is development for getting the information to be as context-aware as possible in order to bring the right information to the user. CDSSs have been developed since 1960's but yet systems are not in broad use. In the 1970s three CDSSs were developed, which give an insight to challenges of CDSSs even today. These systems are next briefly described. (Musen et al., 2014, 649, 655-656.)

2.3.1 Leeds Abdominal Pain System

Developers of the Leeds Abdominal Pain System used Bayesian probability theory and thousands of patient records to calculate the probability of seven possible explanations for patient's acute abdominal pain. The result was available in minutes. The system spread when personal computers became popular. Simple checklists, which needed to be transcribed to a computer, were the input. There has been a question, if the checklists themselves helped clinicians to make better decisions. This is a challenge even nowadays. Perhaps with a more user-centered system design decision making itself could be improved. (Musen et al., 2014, 649-650, 654-655.)

2.3.2 MYCIN

The MYCIN system was based on rules because straightforward algorithms couldn't give the right information when treating infections. Input was lengthy question-answer dialog process, which didn't belong to usual workflow and that added challenges to its adoption. As mentioned earlier, right information at the right context is essential. These factors need to be carefully considered when building a system. System should be integrated to existing workflow and not cause too much distractions. (Musen et al., 2014, 650, 654-655.)

2.3.3 HELP

HELP was integrated in a hospital's information system adding ability to generate automated alerts if something was abnormal in patient's records. Challenge to this system was that, if information wasn't in the database, it couldn't use it. Keeping patient database up to date is a massive challenge. With defining what information is needed and in what format, there is possibility to win this challenge with evolving technology. Automated alerts can cause more bad than good if the amount of alerts is excessive and the user ignores them. This topic will be later discussed more later on. (Musen et al., 2014, 652, 654-655.)

2.4 CDSSs In Use

The next three clinical decision support systems are presented to give an idea what kind of systems are in the market nowadays. EMBeDS is developed by Finnish doctors (Duodecim Medical Publications Ltd., 2012). IBM's Watson is being used to provide assistance in cancer diagnosis and treatment (Lee, 2014). The Computerized Trauma Reception and Resuscitation system is selected because it is the only CDSS found to address trauma resuscitation (Fitzgerald et al., 2008).

2.4.1 EBMeDS

Evidence-Based Medicine electronic Decision Support is created by Duodecim, which is a scientific society for Finnish doctors. Collaborative model is used to developing and maintaining the system and end-users can develop rules for the system using a web-based collaboration tool. EBMeDS does not have an interface so it is more an engine than a full system. It analyzes structured data in repositories and gives guidelines, reminders and reports as a feedback. The system is integrated to electronic health records or some other similar software. (Duodecim Medical Publications Ltd., 2012.)

2.4.2 Watson

Problem in current healthcare is the data being scattered in too many places. There is so much data that it is hard to find the right information quickly. Watson is one solution to this. Watson is a supercomputer able to process unstructured and structured data from various sources. It provides structured answers. It is also capable to learn from internal and external inputs. End user can use mobile device or desk-top computer to receive results. Watson is currently used in cancer centers to sort through large amounts of data looking for disease patterns. It doesn't just analyze the material but also learns from it. By using Watson the big data in healthcare can be used to help people. In another case Watson was used to make utilization management processes faster. Usually these processes take more than 72 hours but with the new system responses are ready in seconds.(IBM Corporation, 2014, Lee, 2014.)

2.4.3 Computerized Trauma Reception and Resuscitation System

The Computerized Trauma Reception and Resuscitation System (TR & R) decision aid was developed to enhance trauma team professionals' interaction and reduce errors of miscommunication and omission. Figure 2 shows inputs and outputs of the system. The inputs include patient details, pre-hospital data, vital signs, cumulative fluid totals, treatments or procedures and diagnoses. The system outputs are visual prompts, diagnoses and treatments or procedures. Development of this system is described next. (Fitzgerald et al., 2008.)

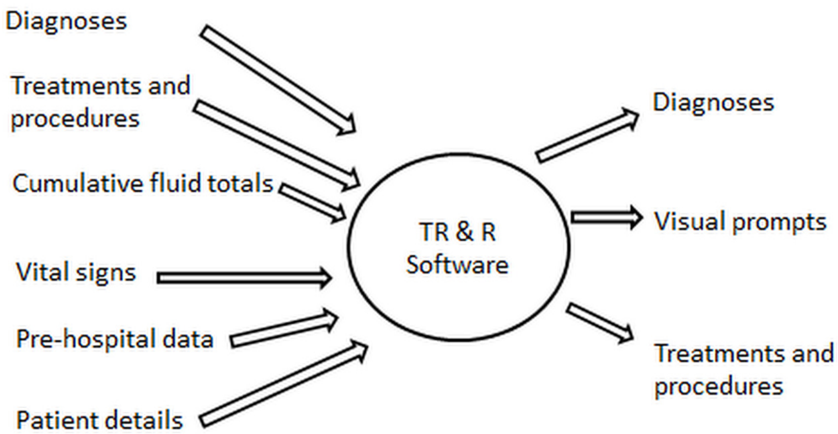

FIGURE 2 Algorithm engine data input/outputs of Trauma Reception and Resuscitation System (Fitzgerald et al., 2008, 8)

Figure 3 shows a simplified interface of the system Fitzgerald et al. (2011) have developed to support trauma team decision making. Algorithm development lasted nine months. 33 experienced staff members, including different roles like surgeons and nurses, analyzed trauma reception and resuscitation current practice and medical literature. Clinical findings, diagnoses, physiologic variables and treatments or interventions were identified as decision triggers. The system was studied in a level 1 adult trauma center. There was a 40 inches wide display for the trauma team and a touch screen for the scribe nurse for operating. The interface includes pre-hospital data, cumulative diagnostic, treatment and physiologic data. Patient's physiologic monitor sends information directly to the system. Section of the physiological information includes data from the prehospital and on arrival information, measures now and a log from previous measures. Information elements in physiological data are time, heart rate, blood pressure, respiratory rate, Glasgow Coma Scale points, temperature, oxygen saturation and the level of carbon dioxide. The intervention prompts were displayed on the big display and on the scribe's screen. The system was found to improve protocol compliance and reduce errors and morbidity in trauma resuscitation even with the experienced trauma teams. (Fitzgerald et al., 2011.)

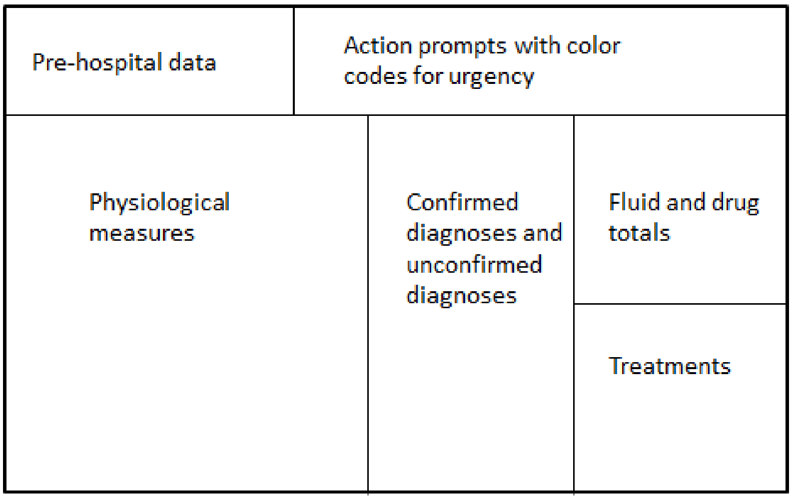

FIGURE 3 The interface of the TR & R (Fitzgerald et al., 2011, 220)

2.5 Mobile CDSS

The trend of mobile systems and applications has arrived to clinical decision support systems. Portability, possibility of customization, low cost and always at hand are the advantages of mobile CDSSs. When using Personal Digital Assistans (PDA's) in healthcare settings improvement in information seeking, clinical decision making and adherence to guidelines are found. Mobile CDSS design guidelines suggest avoiding only text interfaces, not requiring several steps to reach a decision and reducing time to interact with mobile CDSS by integrating it to electronic health record. (Martinez-Perez et al., 2014, Mickan et al., 2014.)

2.6 Challenges in CDSS

There are many studies suggesting design guidelines and frameworks when creating a CDSS. Few things are recurring on different studies, which have researched healthcare professionals and their information system use. The system needs to work fast and not waste user's time with too complex structures. Fitting into user's workflow is very important. The need for learning a new way for doing things should be reduced to minimum. Alarms are important but the alarm mechanisms need to be developed in a way that they really get your attention instead of continuous alarming which makes the user numb. Updating the knowledge-base system is seen as an important thing to provide new and reliable information. (Bates et al., 2003, Horsky et al., 2012, Khalifa, 2014, 422, Sittig et al., 2008.)

It is a challenge for the designers to determine the right amount of flexibility. If information technology solutions are too specific and not flexible they often are difficult to use. If systems are too broad and flexible, they can be too complex to use. Sources of variation in clinical workflow were studied by Militello et al. (2013) via ethnographic observation, focus groups and interviews. They researched eight medical centers to provide implications for the design and implementation of electronic clinical decision support. As a result they found six sources of variability: staffing, pace, perceptions of clinical decision support, technology use during exams, computer and information access. These results help to understand what needs be considered when trying to develop a solution for medical surroundings. (Militello et al., 2013.)

Yao and Kumar (2012) developed a framework called CONFlexFlow and built a prototype based on it. The system takes into consideration flexibility and adaptability of clinical workflow as well as detailed contextual information (Yao & Kumar, 2012). Another workflow oriented framework was built by Jalote-Parmar and Badke-Schaub (2009) to integrate the situation awareness theory and a system design for designing an expert decision-making system to improve decision-making. This framework has been used in designing an intra-operative visualization system, which was found to improve decision-making when compared to traditional ultrasound guided procedure (Jalote-Parmar and Badke-Schaubm 2009). Bayesian network decision support models for CDSS were presented in Yet, Perkins, Rasmussen, Tai & Marsh (2014) to help reflect complexity clinical decisions even when there is not enough patient data.

3 NEED TO BE AWARE

Why somebody should be aware of something? If you are aware you can make better decisions, which results in better outcomes. In this thesis focus is on situation awareness (SA) in trauma resuscitation. SA means all the things which you are supposed to be aware of in a certain situation. In addition to situation awareness there are different types of awareness like social, spatial and temporal. Kusunoki, Sarcevic, Zhang & Yala (2014b) studied emergency medicine clinicians to discover what kind of awareness needs support their work environment. Four facets were found and are presented in table 2. Nilsson (2014, 13) justifies need for using term situation awareness to get specific but also broad enough for covering all aspects by stating: "Taking this path means that there will be overlap and dependencies between types of awareness when looking at information that will be relevant for awareness."

TABLE 2 Awareness facets according to Kusunoki et al. (2014b)

Social and spatial awareness— team member awareness	who is leading the event, who is responsible for certain tasks, who is available to assist with additional tasks, and what roles are present, absent or en route.
Temporal awareness—elapsed time awareness	the estimated time of the patient's arrival, time since the patient arrived, time since interventions or certain tasks, and time since changes in patient status.
Activity and articulation awareness—teamwork-oriented and patient-driven task awareness	contextual information about the patient (object of work), feedback information for task completion, the status and progress of individual tasks, and how each task affects the progress of other tasks.
Process awareness—overall progress awareness	what procedures and interventions have been performed, what protocol step the team is currently working on, and what still needs to be completed to stabilize and transfer the patient.

Situation awareness is the topic of this chapter. First situation awareness theory is explained. Next team situation awareness, situation awareness measures and challenges in medical domain are discussed. In the final section two systems supporting situation awareness in trauma resuscitation are introduced.

3.1 Situation Awareness

Endsley and Jones (2012, 13 referencing to Endsley (1988)) define situation awareness as ”the perception of the element in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in near future.” According to Endsley and Jones (2012, 14) there are three levels of situation awareness: Level 1 is perception of the elements in the environment, Level 2 is comprehension of the current status and Level 3 is projection of future status. These are discussed next.

3.1.1 Situation Awareness Levels

Presented in figure 4, Perception of needed data can be collected using senses such as visual, auditory, tactile, taste, smell or their combination. Confidence in information is as important as the information itself. A physician uses all senses to examine a patient. A wine maker uses taste, smell and visual senses to determine, if the wine is good. In addition to verbal communication, also non-verbal communication form information. Perception isn’t easy to gain. In their study Jones and Endsley (1996) found that 76 % of errors made by pilots related to not getting the needed information. It is important to acknowledge user’s abilities to detect and process information when designing a system. The system should make information easy to process even though there were competing information to distract the user. (Endsley & Jones, 2012, 14, 16.)

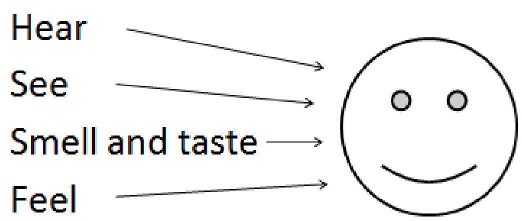

FIGURE 4 Level 1 SA (Endsley & Jones, 2012, 16)

At the Level 2 of SA is comprehension of the current situation. Figure 5 is illustrates this. This means integrating information gained at the Level 1 to user’s goals and objectives. Many times information is gathered from small pieces. The main problem at this level is not understanding the meaning of the information provided. Jones and Endsley (1996) found in their aviation research that about 19 % of SA errors occur at this level. (Endsley & Jones, 2012, 16.)

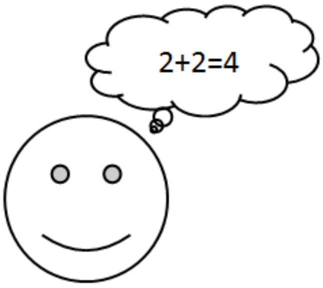

FIGURE 5 Level 2 SA (Endsley & Jones, 2012, 17)

Level 3 SA is projection of future status as seen from the figure 6. To do this, user needs to have good Level 2 SA. User needs to know possible future status to make decisions to alter the outcome it if needed. Endsley & Jones write (2012, 18): "Without sufficient expertise or well-designed information system and user interfaces, people may fail at the early stages of SA, never progressing to Level 3." (Endsley & Jones, 2012, 18.)

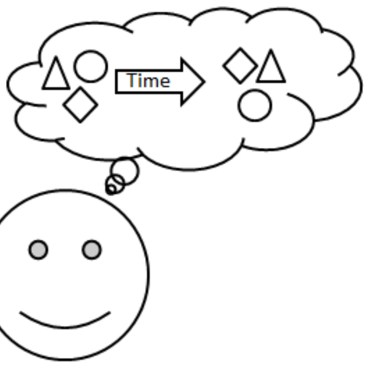

FIGURE 6 Level 3 SA (Endsley & Jones, 2012, 18)

3.1.2 Situation Awareness in Medical Domain

These above mentioned levels applied to medical environment using anaesthelogists' tasks as an example are as follows:

- Level 1 SA includes vital signs, actions of others and equipment functions
- Level 2 SA is synthesizing physical signs and patient information
- Level 3 SA is about understanding what happens after drug administration (Wright, Taekman & Endsley, 2004, i68.)

Schulz et al. (2013) created a framework of anesthetist's situation awareness based on Endsley (1995) and Gaba, Howard & Small (1995). This model is presented in figure 7. Sensory input forms the perception level (Level 1 SA). Conscious and unconscious attention distribution affects what sensory inputs are checked. Comprehension (Level 2 SA) and projection (Level 3 SA) are achieved when pattern matching to prototypical situations, medical knowledge, mental models, goals of therapy and medical guidelines are retrieved from a long term memory. A working memory includes SA Levels and a continuous cycle of reevaluation, self-checking and search for alternatives. The working memory needs to store, integrate and process the perceived information as well as updating the mental model continuously. The working memory capacity can exceed and that results in forgetting or not integrating information. This affects developing higher levels of SA. It is important to alternate goal-driven processing with data-driven processing to direct attention on different information. In the goal-driven process the goal directs what is attended to. In data-driven process information directs attention and it might lead to changing strategy to achieve the goal or even the goal itself. Expectation affects information search and also on perception of the information. The mental models are ways for the long term memory to circumvent the working memory limitations. A pattern matching is a process where a similar prior situation makes information gathering easier. This reduces a cognitive workload. Automaticity provides more resources for attention and working memory as the cognitive load reduces. The term automatic can relate to both physical and cognitive tasks. Learned skills, like how to derive a diagnosis, support SA development. (Schulz et al., 2013.)

External factors influencing positively or negatively on the working memory are complexity, interface design, automation and workload. After information is processed in the working memory cycle it evolves to decision making resulting in straight effect on performance or in task management or teamwork which in affect performance. (Schulz et al., 2013.)

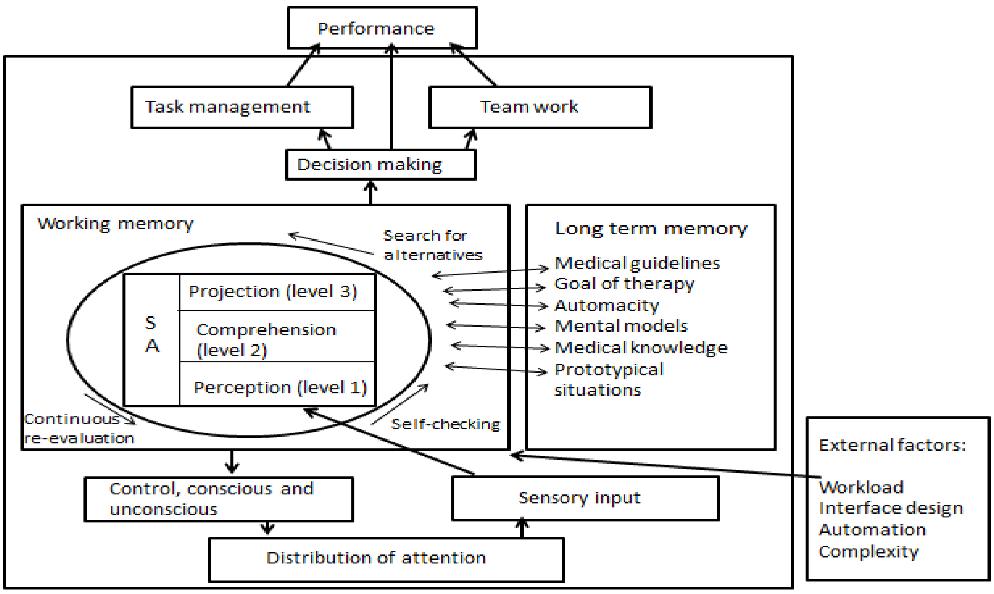

FIGURE 7 The framework of the anesthetist's situation awareness (Schulz et al., 2013, 8)

3.2 Team SA

In addition to individual situation awareness there is a term team situation awareness. Team situation awareness is described as ”the degree to which every team member possesses the SA required for his or her responsibilities” (Endsley 1995, 39). The team SA is as high as the team members’ SA. Figure 8 presents formation of the team SA. Yngling, Nilsson, Groth (n.d., 3) state: ”For all individuals in a team to have the required situational awareness, each individual must be given the information they need, before they need it.” Just a group of people does not mean it is a team. A team consists of individuals who have a common goal. In a team each person has a specific role. interdependence is also a term to describe a team meaning that persons affect each other when doing their job. This is critical to the team situation awareness because the team has a common goal but doing the job pointed to each role means overlapping in some goals. Overlapping in the goals implies overlapping in situation awareness requirements. Shared situation awareness is an important part of team SA. Team situation awareness in the operating room has been studied by Parush et al. (2011) through observation and communication analysis. Their research will be discussed more later on. (Endsley & Jones, 2012,195 - 196.)

Shared situation awareness is seen in figure 8. As team member’s goals overlap, there is a need to share the situation awareness. All information is not important to every team member and it is important to understand what information is needed by which role when designing a system to support situation awareness. Team operations need accurate shared situation awareness for being effective. Coordination is difficult without it. (Endsley & Jones, 2012, 196 - 198.)

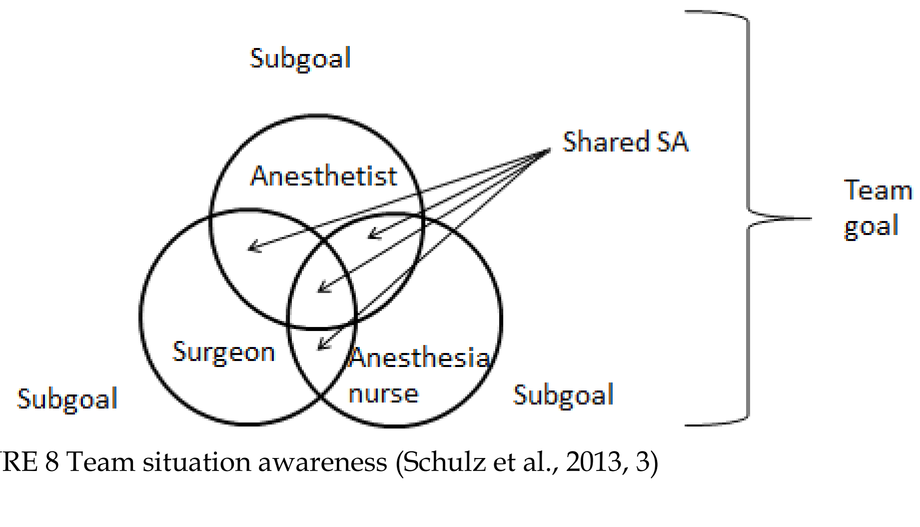

FIGURE 8 Team situation awareness (Schulz et al., 2013, 3)

3.3 SA Measures

SA needs to be measured in order to know if it is on sufficient level or if it needs to be developed to a higher level. There are indirect and direct, subjective and objective SA measures. Metrics applicable to case study are explained here according to Endsley & Jones (2012, 280).

Indirect SA measure approach is found to be the most common in medical literature (Cooper, Porter, & Peach, 2014). These approaches include communication analysis, psychophysiological measures, testable responses and performance outcome. Communication analysis is collected continuously and it will be later transcribed and analyzed. Testable responses means studying participant’s response on beforehand decided events. When measuring a performance outcome of course the outcome of the task is evaluated but the work during the task is too. (Endsley & Jones 2012, 280.)

Williams, Quested & Cooper (2013) suggest eye-tracking devices to SA measurement in health care settings. In their study of integrating wearable technology of Google Glass in trauma simulation Wu, Dameff & Tully (2014) found them effective for improving debriefing sessions and self-reflection. It did not interfere with simulation experience and provided data from team leader's primary visual focus. Improvement on self-reflection and information about team leader’s primary visual focus are important factors on developing better situation awareness. (Wu et al., 2014.) Eye-tracking falls to the category of psychophysiological measures. These measures are also continuous. (Endsley & Jones, 2012, 280.)

Direct SA measures include SART, SAGAT and real-time probes. SART is a short version of Situational Awareness Rating Technique. It is a questionnaire after the experiment. SAGAT means Situation Awareness Global Assessment Technique. It is a questionnaire style measurement, where data is collected on event where pause is beforehand decided. SAGAT has been suggested to be used in medical domain: ”An objective measure of SA such as SAGAT can provide unique insight into team performance within simulated medical environments as well as individual performance” (Wright et al., 2004, i70). SART and SAGAT can be done using computer or pen and paper. Real-time probes are verbally answered and recorded. (Endsley & Jones, 2012, 280.)

Goal Directed Task Analysis (GDTA)-method is said to be used in identifying task goals, related decisions, and the SA requirements operators need when making decisions to meet their goals. In creating GDTA, a tree structure is formed from goals and subgoals which are gathered from expert interviews. Further interviews identify key decisions for each subgoal and the three levels of SA requirements for those decisions. The requirements are used to develop queries for situation awareness global assessment technique (SAGAT). (Endsley & Jones, 2012, 63 - 65, Wright et al., 2004, i68 - i69.)

3.4 Challenges of SA in Medical Domain

Yngling et al. (n.d.) studied trauma team exercises and discovered that when the team has a high situational awareness, they act more organized and in a team where situational awareness is low, misunderstandings or not registering given information are problems. SA has been studied in healthcare settings especially in anesthesia and operating rooms. Situation awareness is context sensitive but these studies apply to emergency care settings where trauma teams work. An anaesthesiologist and a surgeon are part of the trauma team formation.

To build and maintain situation awareness in the OR, information needs to be extracted from many sources: patient monitors, patient examination, laboratory test results and past knowledge of the patient status. Information gathered needs to be integrated to the information of patient's medical history and earlier professional knowledge. There are four typical information loss circumstances. First is a communication breakdown. OR personnel can retrieve information from the display after an interruption or a distraction. Second is missing the pre-operative briefing. If a person comes in late, information can be seen from the display to get an idea of the patient case. Third circumstance is intra-operative handoff. If a worker has to step out for a while, it is easy to get a grip on things done in the meanwhile. Last information loss circumstance is about emergencies, errors and failures. If there is a complication, it is seen what has been done and what has not been done. (Parush et al., 2011.)

According to Vannucci and Kras (2013) common cognitive errors include for example diagnostic anchoring and overconfidence. Diagnostic anchoring is a situation where focus is too early on specific symptoms and new elements do not lead to adjusting the diagnosis. Being too confident of own decisions and judgment can cause problems. Errors in communication are stated to lead to failures. There is also a possibility to trust too much on monitors to tell if something is wrong. These are a challenge to the situation awareness. (Vannucci &Kras, 2013). Attentional tunneling, requisite memory trap, workload, anxiety, fatigue, and other stressors, data overload, misplaced salience, complexity creep, errant mental models and out-of-the loop syndrome are SA challenges described by Endsley and Jones (2012, 31) that can occur when trying to gain and maintain situation awareness.

3.4.1 Attentional Tunneling

Situation awareness within complex domains involves being aware of what is happening across many aspects of the environment. A scan across needed information may occur over a period of seconds or minutes to stay up-to-date. Good situation awareness is highly dependent on switching attention between different information sources. In attentional tunneling people fixate on one set of information and exclude others. That means they aren’t aware of all aspects of the environment anymore. Designing a system to support global SA, making critical cues for schema activation salient, taking advantage of parallel processing mechanics, directly supporting the alternating of goal-driven and data-driven processing, minimizing information filtering and being careful with alarms are things to do for minimizing risk of attentional tunneling. (Endsley & Jones, 2012, 32, 289.)

3.4.2 Requisite Memory Trap

Short term memory is important for SA. Systems should be designed in a way that user's memory doesn't overload. There are many ways to try minimizing the overload. Information should be organized around goals. SA Level 2 information needs are to be presented directly to support comprehension. SA Level 3 projections need assistance. Reducing complexity and ensuring the information are also something to consider. (Endsley & Jones, 2012, 35, 290.)

3.4.3 Workload, Anxiety, Fatigue and Other Stressors

These abovementioned things reduce person's information processing capacity and bring up the need for design systems to provide right kind of information. Stressors can be cognitive or physical making them impossible to eliminate. That is why systems need to be designed to support user when mental capacity is under stress and therefore mental capacity is decreased. (Endsley & Jones, 2012, 35-36, 290 - 291.)

To reduce effect of stressors following principles are proposed by Endsley and Jones (2012, 290 - 291):

- Organizing information around goals
- Grouping information based on levels 2 and 3 requirements and goals
- Limiting time to decode an alarm
- Taking advantage of parallel processing
- Using redundant cueing
- Not making people rely on alarms
- Making critical cues for schema activation salient

3.4.4 Data Overload

Large amounts of data can reduce SA because brains can handle only limited amount of information. Creating user centered systems by studying real information needs and tailoring the system according to them reduces data overload. Organizing information around goals and taking into account the requirements of levels 2 and 3 are ways to ensure right information is presented. Creating coherence, reducing display density and assisting with information needs for levels 2 and 3 are also things to consider for data overload reduction. (Endsley & Jones, 2012, 36 - 37, 291.)

3.4.5 Misplaced Salience

System designers need to be careful with bright colors, flashing lights and moving icons because they can distract the user from the important information or cause the brains to block out all competing signals. Key principles for misplaced salience: Minimizing false alarms and their interfering with ongoing activities, selecting carefully the information presentation needs, using data salience to support certainty, supporting shifts between goal- and data driven processing and explicitly identifying missing information. (Endsley & Jones, 2012, 38, 291 - 292.)

3.4.6 Complexity Creep

Too many features make a system too difficult to use and it results in unexpected behavior. Careful design is required in order to avoid complex systems. Only truly necessary features should be added, existing features should be organized and prioritized, system's logic should be consistent, conditional operations need to be reduced and system design should minimize task complexity. Automation can help, but there are few things to consider in design: use automation only when necessary, minimizes rules to remember, enforcing automation consistency and transparency. (Endsley & Jones, 2012, 39, 292 - 293.)

3.4.7 Errant Mental Models

If people are using a certain mental model to do a thing, it is hard to change the mental model. Standardization and limited use of automation are said to be key tenets that can help with this error. User can be assisted to develop mental models by mapping system functions to the established mental models and the goals, standardization and consistency of controlling systems and displays, enforcing automation consistency, system and automation transparency and observability, salient system states and modes. (Endsley & Jones, 2012, 41, 293.)

3.4.8 Out-of-the-loop Syndrome

Automation is a part of everyday life. There are situations when automation is important and good to have. Automation has some down sides and people should not trust automation too much. One needs to be aware if automated things aren’t running as planned to intervene before it’s too late. There are many principles to design automation into systems. To name a few: thinking if automation is really needed, providing SA support rather than decisions and allowing user to be in the loop and in control. (Endsley & Jones, 2012, 42, 293 - 294.)

3.5 Systems to Support SA

The earlier mentioned model of situation awareness model (figure 7) describes how situation awareness and decision making relate to each other. Salfinger, Retschitzegger & Schwinger (2013) made a survey of situation awareness systems, which are supposed to gain and maintain situation awareness to help humans. Maritime surveillance and driver assistance were main types but there was not mention about systems in healthcare domain. This leads to believe that situation awareness support systems in healthcare domain are rare. In the following text support systems for situation awareness and decision making in the trauma team context are presented. Sarcevic with Xhang and Kusunoki have studied assisting the trauma team's decision making with IT solutions for many years. Sarcevic has made a study in 2007 which is similar to this study. In her study interviews were done in focus groups and the participants were physicians and trauma nurses. Recently Nilsson has done research in this area and focus is to provide means to support actions of a remote expert in the trauma team.

3.5.1 Sarcevic

Sarcevic and her research team aim to develop an information technology solution to support the trauma team activities. They have published several articles regarding information needs (Sarcevic, 2007, Sarcevic & Burd, 2008, Sarcevic, Marsic, Lesk & Burd, 2008, Zhang, Sarcevic & Burd 2013), information sources (Sarcevic 2012) and decision making tasks (Sarcevic, Zhang & Kusunoki, 2012). Checklist-type system is proposed in Sarcevic & Burd (2009) to solve problems in retaining information. A prototype of a digital pen, which reflects writing from a special flow sheet to a display, is presented in Sarcevic Weibel, Hollan & Burd (2011). Recently they have developed a prototype of a display (see figure 9, Kusunoki et al., 2014a).

As stated before, Sarcevic (2007) investigated information sources of the trauma team members. The results are presented in table 3. She used interviews, focus groups and video recordings of trauma resuscitations to provide information for deriving requirements for designing a decision and communication support systems for trauma teams. Four information sources were found including patient, vital signs monitor, x-ray images and other team members. Roles of senior resident, physician, scribe nurse, primary nurse and a pharmacist. There are four phases: before patient arrival, upon patient arrival, primary survey and secondary survey. Information before patient arrives is mostly constant and not depending on roles. Estimated time of arrival is important to all.

Patient age is mentioned everybody but to the physician. Senior resident, physician and scribe nurse are interested in the patient's status during transport. When patient arrives details of the injury mechanism interest all. Updated status interested everybody except physician. In addition the senior resident and the pharmacist want to know about allergies. On primary survey vital signs are the most needed information. Airway patency, breath sound status, pupils and neurological status interest both the senior resident and scribe nurse. Physician tries to build up the general view of the overall situation. Primary nurse is interested in fluids, IV gauges and blood tests. Patient history for having information about medications is important to pharmacist. In secondary survey additional tests interest the senior resident, the physician, the scribe nurse and the primary nurse. The nurses are also interested in transferring the patient to another unit.

TABLE 3 Specific information needs of the core trauma team in different phases of resuscitation (Sarcevic, 2007, 9).

Phase	Senior resident	Physician	Scribe nurse	Primary nurse	Pharmacist
Before patient arrival	• Estimated time of patient arrival • Severity of injury • Status during transport • Patient age	• Estimated time of patient arrival • Urgency • Availability of trauma team • Status during transport	• Estimated time of patient arrival • Status during transport • Patient age	• Estimated time of patient arrival • Mechanism of injury • Number of patients • Means of transport • Patient age	• Patient age
Upon patient arrival	• Details of injury mechanism • Updated status • Allergies	• Nature of injury	• Updated status • Details of injury mechanism	• Updated status • Details of injury mechanism	• Allergies
Primary survey	• Vital signs • Airway patency • Breath sound status • Pupils • Neurological status	• Vital signs • Overall overview of situation	• Vital signs • Airway patency • Breath sound status • Pupils • Neurological status	• Vital signs • Volume of fluid needed • Size of IV gauges • Blood tests to draw	• Patient history (medications) if available

(continues)

Table 3 (continues)

Secondary survey	• Whether or not additional tests are needed	• Whether or not additional tests are needed	• Patient transfer to another hospital unit • Types of additional tests	• Patient transfer to another hospital unit • Types of additional tests	• n/a

Sarcevic, Xhang and Kusunoki (2012) have studied decision making tasks in trauma resuscitation. They interviewed five team leaders and four emergency department (ED) physicians and one surgical fellow about decision making tasks, information sources and what aspects make the decision making difficult.

Three decisions were found to be made in the beginning of treatment. First decision is determining if patient needs surgery based on pre-hospital information. Need for CT-scan is then decided and that is based also on pre-hospital information or physical examination. Third decision is about possible need for additional staff. After these decisions team leader follows the protocol with information gathered during each step. (Sarcevic et al. 2012.)

The information sources found are similar to discoveries of Sarcevic (2007). In addition to previous research Sarcevic et al. (2012) mention patients and team members. A glance at the patient provides useful information for decision making. The team members acquire different information. Information exchange is important when trying to provide all relevant information to support decision making.

Aspects like system complexity and diagnostic tradeoffs, communication breakdowns, information reliability, severely injured or multiple patients are reasons for difficult decision making. Trauma patients are complex because there are many possible injuries and symptoms. Also the decisions need to be made fast and there isn't much time to discuss about them. If a surgeon doesn't have a supervisor he/she has to make decisions based on similar cases in the past and training. Communication is essential to maintain awareness. Room is said to be noisy and crowded but leaders still get the information they need but the lack of reporting information aloud is the main problem. Information needs to be reliable when used in decision making. Pre-hospital and sensor information are something what needs to improve as they now are sometimes unreliable. When there are many patients or severely injured problems arise with information gathering and retention as rapid response is needed. (Sarcevic et al. 2012.)

In the final display version of Kusunoki's design (see figure 9 for simplified version) there is a lot of information gathered around figure of a patient in addition to markings on the figure. Background information is on top left corner telling patient's age, weight, injury mechanism and energy. Another block at the top tells pre-hospital interventions. In the top right corner are timer since patient has been treated and arrival time. On the left side are procedures and secondary survey results. Glasgow Coma Scale is presented next to the patient figures head. The patient figure shows procedures and abnormal findings. On the right side are treatments with dosage and time when it is given. Right bottom boxes include laboratory orders and results. In their display prototype vital signs are not shown at this point because they are thinking what would be the best way to include them. (Kusunoki et al., 2014a.)

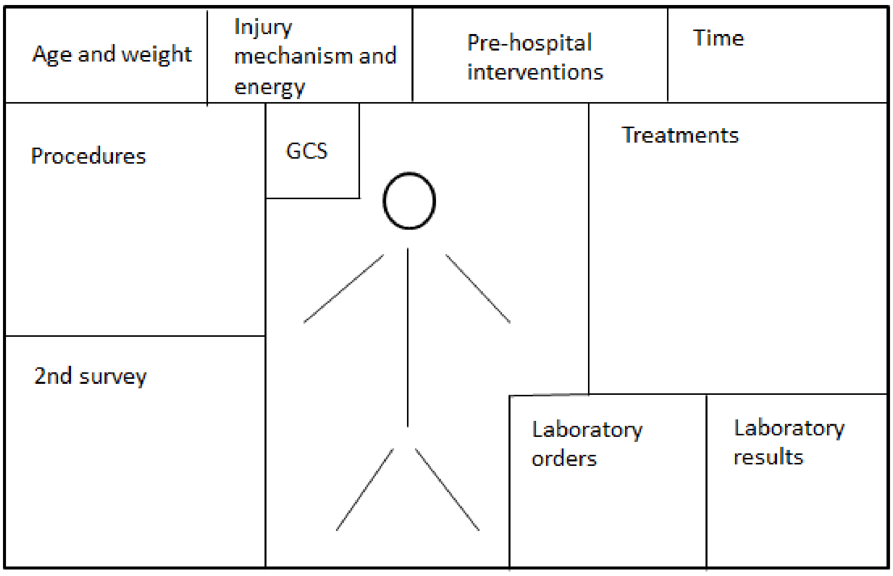

FIGURE 9 Display design evolution (Kusunoki, 2014a, 3782)

3.5.2 Nilsson

Nilsson (2014) studied what information experts need in order to remotely support the trauma resuscitation team. They observed 18 training sessions and eight real trauma resuscitations and used questionnaires to analyze situation awareness of trauma team members taking part in thirteen trainings. In training sessions they tried their remote expert system including screen showing vital signs, another with picture of the room and third having picture from camera mounted on surgeons head. Vital signs were found to be most important source of information and video or image sources were useful but not that important.

After studying information needs they spent three years building a prototype using participatory design process with mainly surgeons and radiologists. Different interface designs were made and finally one was selected to be used in a prototype for tablets, which is shown in figure 10. As vital signs pulse, saturation and blood pressure are things to appear on screen. In the center there is a timeline telling vital sign measures and actions performed. In the left bottom corner is a small video screen showing the trauma room. There are ATLS-protocol steps on the left side. The steps are described with letters A (airways), B (breathing), C (circulation), D (disability) and E (exposure). Green color means that everything is alright. Red color means that there is an issue. Grey color indicates that there is no value set. On the left side on the bottom of the protocol steps is the time when trauma resuscitation has started. On the right side bottom of vital signs is the time that has been spent on resuscitation. Single pictures from the situation can be attached to the timeline. In the left bottom corner is an image presenting a video from the trauma room. If an object is selected, more information is provided to the empty area at the bottom. (Nilsson, 2014.)

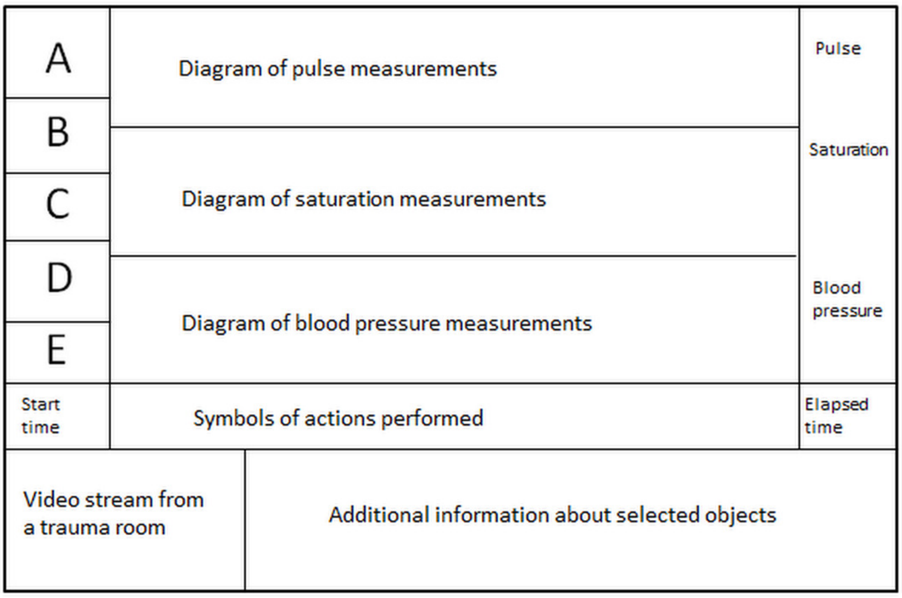

FIGURE 10 The mobile interface prototype for the remote expert (Nilsson, 2014, 42)

4 RESEARCH METHOD

Chapter four describes the methods used in this study. In first section research approach is explained. Next there is a brief introduction to the case hospital. Following chapters tell methods for research strategy, data collection, result validation and data analysis in detail.

4.1 Research Approach

This thesis has a constructive approach to understanding end user needs for an information system. The process for this thesis began with a meeting in December 2013. In the meeting there were present the writer, two supervisors and two surgeons. As a result research focus was set on the trauma teams and situation awareness. The trauma team activity occurs randomly and it was decided to study trauma team exercises, which are done in real environment with real teams using a patient simulator. Research team constructed of thesis worker, two supervisors, two physicians, who act as surgeons or trauma team leaders in trauma resuscitation and an anesthesiologist who is responsible of trauma team exercises. Research approval was applied from the hospital.

In the research the previously described GDTA method was used to some extent for discovering goals and and decisions of the trauma team members. Earlier mentioned two surgeons and the anaesthesiologist were first interviewed as experts of the subject matter. Then 12 trauma team members were interviewed. After these interviews the analysis of the answers was discussed with the experts. A large tree of decisions and situation awareness needs was not built. Instead, a information matrix was built. It was used to visualize the important information.

For the literature review databases and search engines were used. A few databases were found to match area of the thesis. These databases were Medline, Medic and Cinahl. In addition Google Scholar helped to find articles. Main search phrases were "clinical decision support system", "situation awareness" and "trauma team".

4.2 Introduction to Case Environment

The Central Finland Health Care District is the fourth largest health care district and the largest non-university health care district in Finland. The district provides services for 250 000 inhabitants. The Central Hospital is located in Jyväskylä and there are about 400 beds. (Keski-Suomen sairaanhoitopiiri, 2014.)

The trauma resuscitation takes place in an emergency department where a shock room has relevant equipment for stabilizing the patient. There are four beds. There is a computer at the corner of the room. In the trauma resuscitation it can be used for checking electronic health records. On the left side are two monitors. The smaller monitor shows values from vital signs. The bigger monitor has been used for checking laboratory results but that is no longer possible due to technical issues. There are many wires and tubes which can get in the way.

Appendixes 1, 2 and 3 present the paper forms, which are in use at the trauma resuscitation. Information gathered nowadays to these forms is the same information that an information system could help with in the future. Next the forms are explained to provide insight on important information these forms include.

Appendix 1 is "Ennakkoilmoituslomake" which means the pre-arrival information form. The form is a one sided size A4 paper. On the top side of the page is the basic background information. These are name of a reporter, name of a patient and a patient's social security number. Next come lines for describing what has happened, when the symptoms have started and when the patient has been seen to be moving. Information about Marevan medication has checkboxes, yes or no. Information about the use of the Marevan, which has a tradename "Varfarin", medication is important because it has an effect on blood coagulation. In the middle of the page are boxes regarding breathing, circulation, consciousness, CGS and medical treatment. At the bottom of the page are few lines. First is information about date and time of the received pre-arrival information. Next are an expected time of arrival and a name of the person who answered to the pre-arrival information phone call. The checkboxes at the bottom are a list of roles which are notified.

Appendixes 2 and 3 are part of a triage form. The form is a double sided size A3 paper. Only the other side is in use at the trauma resuscitation. Appendix 2 is the part of the triage form, which includes the basic information about the patient case. A name, a date, a place and the symptoms are described to the top of the page. Next are checkboxes for ability to function, airways, breathing, pulse, GCS, pupils and pain. Triage class is marked to a letter scale. A is for urgent patients and E is for the cases, which can wait for a while if necessary. Weight, height and information about eating and drinking are written with information about allergies. Under these sections there are checkboxes for child services. Additional information can be written to a designated area with a signature of a triage nurse. A table at the middle of the page enables writing the values of physiological measurements and the time of the measurement. At the bottom there are sections for information about GCS, contacting family, property, devices and clothes. Appendix 3 is the second page of the triage form. On the top there are spaces for names of a physician and a nurse. On the top left section are topics for given infusion, medication and blood products. Under that section there is a section for examination results. The big section on the right side is for monitoring the patient, treatment procedures and responses to treatments and medication. A field for time of the abovementioned findings is on the page.

4.3 Data Collection

The data collection had two phases. First the trauma team exercises were video recorded and later semi-structured interviews were conducted.

4.3.1 Video Observation

The trauma team exercises are held four times a year and patient case themes change accordingly. There are two four day exercise events in the spring and in the autumn. A four day period includes 11 exercises which you can sign up by e-mail. One exercise session includes a short theory session and two different patient cases with debriefings. The observed exercises took place in April 2014.
11 exercises were planned to be held but 9 were held. Two exercises were cancelled because there were not enough participants. One exercise was not recorded because of technical difficulties. 8 exercises were video recorded. There were teams where the trauma team educator had to play a variable roles due to missing personnel. A trauma team core consists minimum of a surgeon, who examines the patient and leads the team, an anaesthelogist, who is responsible of breathing and blood circulation, an anaesthesia nurse, who is assisting anaesthelogist and a trauma nurse, who is assisting surgeon and tries to write down information about the patient and procedures. A radiologist, a scribe nurse and a laboratory nurse are also members of the trauma team.

To this study, a car crash patient case was selected to be studied even though all eight exercises and debriefings were video recorded. Personnel attending to exercises did not know about the research beforehand. In the beginning of the exercise research was introduced. A permission to record the exercises and debriefings was asked from the participants and an opportunity to volunteer for later on held interviews was given. Interviews were said to last for 30 minutes during work hours at the hospital. This was to ensure willingness to participate. Supervisors were involved with decision about the interview length. 28 volunteers signed up for interviews; 5 surgeons, 8 anaesthelogists, 8 anaesthesia nurses and 6 trauma nurses. In addition one field officer and a nursing student signed up. One trauma nurse's e-mail was not active and could not be reached when trying to be contacted. Field officer from emergency medical services was not contacted because he would have been the only interviewee from his role and the aim was to get a few interviewees per role. The nursing student was contacted as he was thought to have skills for operating in a trauma team situation.

Car crash exercise videos were observed to get an idea of trauma team activities and to enhance mutual language in the interviews. Debriefing video recordings were transcribed to form basis for interview questions. Interview questions were approved by research team. Interviews took place in summer 2014. Sixteen interviews were the goal and 15 were done.

4.3.2 Semi-structured Interviews

12 volunteers (44%) were interviewed from the 28 volunteers. Every role is presented with three individuals. In addition three experts were interviewed bringing the total number up to 15. Two of the experts act as surgeon in trauma resuscitation and one acts as an anaesthesiologist. That adds up to five surgeons, four anaesthesiologists, three trauma nurses and three anaesthesia nurses. Table 4 summarizes respondents' trauma team roles.

TABLE 4 Respondents' trauma team roles

Trauma team role	**Number of participants**
Surgeon	5 (including two experts)
Anaesthesiologist	4 (including one expert)
Trauma nurse	3
Anaesthetic nurse	3

Figure 11 summarizes respondents' work experience years in healthcare and in trauma team. There are different work experience levels among different roles varying in trauma team experience and in healthcare experience. Trauma team activity like it is nowadays started about 14 years ago. One surgeon and two anaesthesiologists have been involved from the beginning. Of course trauma cases have been treated in some fashion before trauma team. Four surgeons, one anaesthesiologist, all three anaesthesia nurses and all three trauma nurses have five or less years' work experience in trauma team. Two anaesthesiologists, one surgeon and one trauma nurse have 20 years or more work experience in healthcare. There are three surgeons, one anaesthesiologist and one trauma nurse having five or less years as a work experience in healthcare.

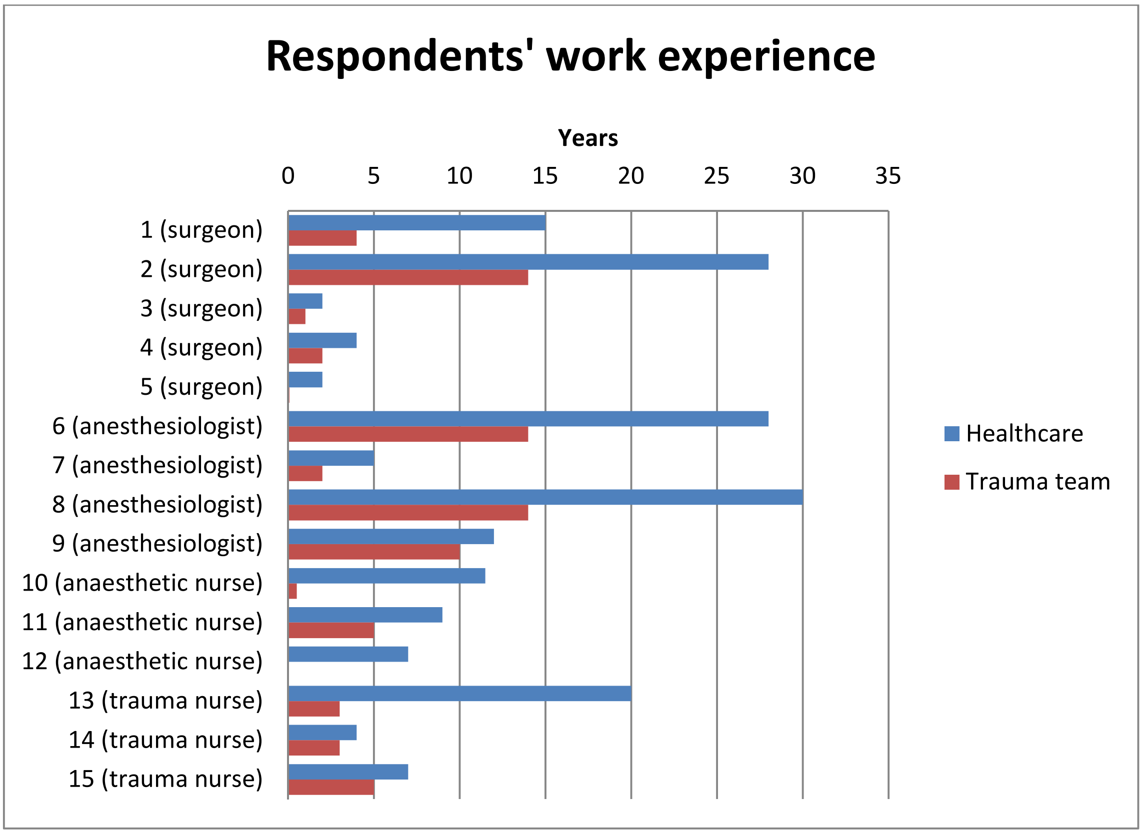

FIGURE 11 Respondents' work experience

Studies took place at the hospital. An exam room was available for interviews to provide a quiet place but still close to work station. Some interviews were made elsewhere at the hospital if the responded asked due to being on duty. These places were also quiet places and there were no disturbance. In the beginning of the interviews a short description of the study was explained. As a background information role in the trauma team, experience in healthcare and in the trauma team activities were asked. Next was told a trauma scenario which resembles video recorded car crash situation:

- Passenger car and tank truck have crashed
- Driver of the passenger car is coming
- Speed has been 80km/h
- Complains chest, hip, stomach from the left side. Sore left wrist.
- Breathing sounds quiet from the left side
- Pressure 132/71, hear rate 88
- Oxygen saturation 98
- Additional oxygen 5 liters
- Is conscious
- One drip

After describing the scenario the respondent was asked to tell an ideal process from his/her role's point of view. Decision making points and the information needed to make the decisions were asked. Also real life processes and how they differ from the ideal processes, risks and IT challenges were questioned. Since the interviews were semi structured there was discussion about other topics depending on respondent's interest. Below are the interview questions translated in English. All the interview questions are available in the appendix 4 in Finnish.

Background information:

- role in trauma team
- work experience in health care
- work experience in trauma team

Main questions:

- Describe shortly the ideal process beginning from the trauma alert call and ending to patient being transferred from the shockroom
- What is your main goal?
- What subgoals are related to main goal?
- What are decision making pain points?
- What decisions are related to subgoals?
- What information do you need to make a decision?
- Why do you need the information?
- How the information helps you to achieve your goal?
- What is the most unforgettable complication?
- Was some information wrong at that time?
- What thing is the best organized in trauma team activities? Why?

Additional questions:

- What is critical information?
- In your own experience, what are the most relevant risks?
- How real life process differs from ideal process?
- What is usually ignored?
- What information was needed to make the situation better?
- What kind of example can you tell about a person who has good situation awareness/sense?

4.4 Result Validation

Discussions with experts helped to validate results. Three or more respondents per role helped to get a whole picture of role's needs even though if somebody forgot to mention something. Pre-hospital information indicates that everything else is alright and the only abnormal finding is that the breathing sounds are quiet. This can lead to interviewees not mentioning other information when describing the workflow. Interviews were done in Finnish and transcribed to Finnish and also discussed with experts in Finnish. Selected citations were translated to English for supporting arguments in thesis. Translation was done as carefully as possible to avoid information getting lost due language. Experts helped with the medical terms in Finnish and English.

4.5 Data Analysis

The first analysis was made from the interview audio recording transcriptions. The transcripts were put on walls to create a collage based on interview questions. A color coding was used to sort different roles. Numbering was used to separate respondents. Information elements were underlined. Mind maps and simple flow diagrams were then developed based on underlined elements. Next the analysis was discussed with the experts to find out possible misunderstandings.

Two matrixes were then developed from the information elements mentioned in the interview transcripts. The matrixes are sectioned according to information needs during workflow. The first matrix is presents information needs before the patient arrives and the second matrix shows the information needs when the patient has arrived. In the first matrix the workflow supports gaining situation awareness. Trauma team wants to know background information in addition to pre-arrival information for generating an understanding of the situation. After gathering this information they can suspect the problem. Then they think about what is needed for treating the patient. In the second matrix the information is gathered to maintain situation awareness. Different measures and information straight from the patient is relevant at this point.

From the matrixes it was easy to notice the important factors for the trauma team as a whole and for each role. The information elements in the matrix were color coded. Colors are based on mentions within a role. Yellow is used for one mention. Green is for the elements, which are mentioned by half of the respondents. If an element was mentioned by more than a half of the respondents in a role, it was marked red. If an element got two or more red boxes it was bolded. Two boxes were enough for bolding if those were from two physicians or two nurses. This is because these roles have different goals and mentioning elements is dependent on these goals. The bolded elements were used to further develop the situation awareness model of Schulz et al. (2013, 8).

5 RESULTS

In this chapter the results are presented. First information flow during trauma resuscitation is told to give an idea of the trauma resuscitation situation. Next trauma team's information needs are presented as quotes from the interviews and as matrixes built from information elements mentioned in interviews.

5.1 Information Flow During Trauma Resuscitation

Trauma situation begins when paramedics call the hospital to let nurse on duty know the pre-hospital information which is written on a paper form. Appendix 1 presents the form.

The nurse on duty calls the surgeon on duty and tells the pre-hospital information. Surgeon then decides if the situation requires a trauma team. If a trauma team alert is made, nurse on duty and the surgeon call other members as protocol demands. When calling the pre-hospital information is told if there is enough time. At least the call contains words "Trauma team alert, in x minutes".

Ideally trauma team gathers at the shock room 5-10 minutes before the patient arrives. Background information of the patient is collected from electronic medical record (EMR) system. If the pre-hospital information is thought to be too little field officer in duty can be called to try get more information. Pre-hospital information is told to trauma team and also the paper including information is at the scene. It is seen important to gather as a team before patient arrives to develop a consistent view of the situation and discuss about possible actions to take.

> 6 (Anaesthesiologist): In a trauma alert ideally the team would be five-ten minutes before the patient at the shockroom. Then there is time to go through what is possibly coming, check pre-hospital information, what is known about previous illnesses and medication if there is something remarkable for example potentially causing hemorrage or medication affecting blood coagulation. Thinking what potentially has

> happened according to pre-hospital information and where the patient probably is broken.

When the paramedics bring the patient he or she has transportable vital signs monitors attached telling current measurements and also an oxygen mask might be on the face. Trauma team quickly makes an assessment of the patient which takes few seconds. Then paramedics report what has happened, what injuries have been found and how the patient has reacted to given treatments.

> 3 (Surgeon): There is a need to know what has happened. It is crucial. Then the patient's vitals, blood pressure, oxygen saturation, heart rate and consciousness. What they have been at the time of departure, on the way and what they are when arriving. Has there been a significant change.

How the patient looks and is feeling is also essential. Trauma team leader makes a decision to stabilize, scan or take the patient straight to surgery. In this research scenario stabilizing is the patient is right thing to do. First the vital sign monitors are attached:

> 10 (Anaesthesia nurse): Monitor comes first that you connect. ECG, blood pressure and oxygen saturation are enough at first.

Blood sample for laboratory tests is taken and FAST-ultrasound is made to get an idea of possible injuries which can't be seen from outside. Trauma nurse writes information to triage-form, which can be seen from appendixes 2 and 3. It is possible to ask from the trauma nurse about results if needed but trauma team members usually keep results in their memory when making decisions.

When the patient is stable enough, he or she is taken to trauma CT to get a full picture of the injuries. Surgeon and anesthesiologist discuss with x-ray physician to have a clear understanding about the injuries.

Surgeon and anesthesiologist come back to shock room where the patient has returned earlier accompanied by trauma nurse. Trauma nurse and anesthesia assistant have continued nursing the patient while waiting. Current patient status is acknowledged and further treatment is then decided. Information is transferred by speaking.

Trauma nurse takes the patient to designated place for further treatment. This can be for example intensive care unit or a bed ward if immediate surgery isn't needed. Trauma nurse gives information to receiving end using triage-form and memory when telling the report. With the trauma nurse an anaesthesiologist and another nurse can go along if the patient's status requires.

When the patient leaves the shock room a surgeon writes a report to EMR telling what was done to the patient, what is the treatment plan and how the patient should be medicated, followed up and examined.

5.2 Trauma Team's Information Needs

Tables 5 and 6 show the matrixes, which present clear summaries of information needs of the interviewed trauma team members. Information needs are divided by roles and phases. The first matrix in table 5 describes information needs before patient arrives and other in table 6 as the patient has arrived. Trauma team gains situation awareness from pre-hospital and background information and maintains it with information from patient and monitors.

Before patient arrives background information is gathered from EMR, pre-arrival information from ambulance is told to everyone, a discussion about possible injuries has happened and things are prepared based upon that discussion. The discussion about possible injuries is usually led by trauma team leader but it is a discussion so everybody can say if something needs to be said.

> 12 (Anaesthesia nurse): It is surely extremely important. Everyone forms a certain image from the pre-hospital information that is given. In practice many read and especially the doctors and people in charge read it again and decide for themselves when big lines can be described according to their expectations. When we all have to assemble unite mind. Then we have united preparation. It is now less or more than the level of injury.

Nurses are the ones who gather the equipment sometimes independently and sometimes according to doctor's orders.

> 11 (Anaesthesia nurse): Then I prepare. At the moment patient is on spontaneous breathing so there is no need for a ventilator but most likely the patient needs an artery cannula. I take them ready. The patient has one drip, as there is a probability for another I take equipment ready. I check that cart has everything needed and put them ready. Supposedly there was sore chest and side and I predict and ask from the surgeon if there is a need for chest tube and then I take them ready. So I discuss much with doctors what they want if they don't say but usually they say it.

The most important background information to the trauma team is basic illnesses and medication. Especially anaesthesiologists and surgeons want to know these. Allergies and information about difficult airways were mentioned only once by anaesthesiologists. Addictions to drugs or alcohol were mentioned by one anaesthesiologist and surgeon.

As seen from the table 5 important pre-arrival information were injury energy, injury mechanism, injuries and breathing sounds. Consciousness was mentioned by three anaesthesiologists, two surgeons and one anaesthesia nurse. Vitals were mentioned by every trauma nurse. Oxygen saturation, breathing frequency and drip gathered a few mentions from respondents. There is no mention in the matrix about heart rate or additional oxygen because nobody mentioned them in interviews. Yet these are important information according to one of the experts. As a possible explanation he stated that ECG-monitor tells pulse and rhythm. Regarding additional oxygen he stated that additional oxygen is seen straight from the patient because he/she would be wearing an oxygen mask if additional oxygen is needed.

> 6 (Anaesthesiologist): Injury mechanism, injury energy and injuries occurred are the other side and the other side is that what has been done to it and in it the stability that has been reached and to what amount the patient can stand waiting and additional research.

Possibility for a pneumothorax was major concern for anaesthesiologists and surgeons. Need for blood products was also important to anaesthesiologists. Laboratory tests were mentioned by two trauma nurses. Possibility for a hemothorax and need for anaesthesia were mentioned by few.

Chest tube was mentioned by almost everyone to prepare. Additional drips, artery cannula were things many anaesthesiologists and anaesthesia nurses wanted to prepare. Getting monitory equipment ready was a concern for nurses. Getting ready for intubation was important to anaesthesiologists. Medication for anaesthesia was mentioned only by one anaesthesiologist and need to prepare breathing assistance equipment was mentioned by one anaesthesia nurse.

> 7 (Anaesthesiologist): I think that 80 kilometres per hour and airbags have ejected so it is a major energy injury. Probably big life threating injuries are found from the patient. Being conscious is good so the head probably works. But the weak breathing sounds from the left side means that there can be a pneumothorax. It can develop to a tensionpneumothorax which is life threatening situation. It would be one thing to take care of. Patient has only one drip. In other words we are in trouble if there is a big hemorrage so more drips are needed. Hip can be fractured or something else. I would get ready for these things. I would take drips, chest tube equipment, artery cannula and else ready.

TABLE 5 The trauma team information needs before the patient arrives

		Information	A	S	T	AN
Before patient arrives	Background information	**Basic illnesses**	3	3	1	1
		Medication	3	3	1	
		Allergies	1			
		Addictions (drugs/alcohol)	1	1		
		Information about difficult airways	1			
	Pre-arrival information	Vitals			3	
		Injury energy	3	3	2	3
		Injury mechanism	2	3		2
		Injuries	3	2	2	2
		Consciousness	3	2		1
		Breathing sounds	3	4	2	2
		Oxygen saturation	1			1
		Breathing frequency	1			1
		Blood pressure	1			1
		Drip	1		1	1
	Possibilities	**Possibility for pneumothorax**	3	3	1	
		Possibility for hemothorax	2	1	1	
		Need for blood products	4	1		1
		Need for anaesthesia	2			
		Laboratory tests			2	
	Things to prepare	**Chest tube**	4	4	3	2
		Additional drips	4	1		3
		Medication for anaesthesia	1			
		Intubation	4	2		1
		Artery cannula	4			3
		Breathing assistance equipment				1
		Monitoring equipment			2	3

When patient has arrived the monitoring equipment tell about breathing and blood circulation but information straight from the patient is important too. Oxygen saturation is important information regarding breathing as almost everybody mentioned it. Breathing frequency and breathing in general were mentioned many times. Breathing sounds got only one mention from an anaesthesiologist and a surgeon. Blood pressure is the most important thing in blood circulation. Heart rate is second most important information. Blood circulation in general interests surgeons and trauma nurses. Laboratory results are important to three anaesthesiologists and one anaesthesia nurse. ECG is important to trauma nurses but only one anaesthesiologist and anaesthesia nurse mentioned it. Pulse is mentioned by two anaesthesiologists and two surgeons.

How the patient looks is important to almost everybody. Consciouness is also important to many but only one anaesthesia nurse mentions it. Three anaesthesiologists, one surgeon and two anaesthesia nurses think body temperature is good to know. Information about pain is mentioned by three anaesthesiologists and two trauma nurses. Breathing mechanics are important to some, assessing for joint or bone stability and open airways for a few. Table 6 summarizes these findings.

> 9 (Anaesthesiologist): You can see it from the face. And if the lips are very blue then the oxygenation is not good enough. Difficulty in breathing meaning that if one can speak in full sentences then lungs are probably ok. If there is something then patient has to puff. It can be seen really fast. Saturation and pressures are important. There should not be any delays when transferring from paramedic's monitors to our monitors. Saturation, pulse and blood pressure needs to be available at all times. I quickly put continuous blood pressure measuring, insert a cannula. Meters are slow and they can be attached wrong, there can be a surprise delay before blood pressure is measured.

TABLE 6 The trauma team information needs when the patient has arrived

		Information	A	S	T	AN
When patient has arrived	Breathing	Breathing in general		2	2	
		Oxygen saturation	4	3	3	2
		Breathing frequency	2	2	2	
		Breathing sounds	1	1		
	Blood circulation	Blood circulation in general		3	2	
		Blood pressure	4	3	3	2
		Heart rate	1	3	3	2
		Pulse	2	2		
		ECG	1		2	1
		Laboratory results	3			1
	Information straight from the patient	**Consciousness**	4	3	2	1
		Body temperature	3	1		2
		Looks	3	3	3	2
		Airways open	1	2		
		Breathing mechanics	2	1	1	1
		Assessing for stability (joint/bone)		2		
		Pain	3		2	

5.3 Main Goals of Trauma Team Members

Table 7 shows the main goals of trauma team members. For anaesthesiologists and surgeons keeping patient alive is the main goal and of course that is main thing for nurses too but they try to reach it by providing assistance to physicians and monitoring patient's vital signs. A surgeon is the team leader according to instructions so many of the main goals are associated with that task.

> 9 (Anaesthesiologist): Keep the patient alive. Prevent further damages.
>
> 2 (Surgeon): The main goal is divided in two. First using the human resources rationally what is available. And of course for the best interest of the patient so that core information of the patient is quickly gathered and treatment can be focused on things which are important in the early phase. That demands two things. Or actually one thing why trauma team exists and using it is being rehearsed. To utilize roles to the maximum. I don't think it is more complicated than that.
>
> 3 (Surgeon): Examine the patient thoroughly and find the essential injuries. Making work diagnoses and presenting them to the team leader in a order which is rational for future treatments, what should be examined first. What are the next steps based on those findings.
>
> 11(Anaesthesia nurse): Anaesthesia nurse's role is to be helping hand to anaesthesiologist and monitor patient and check that vitals are ok.
>
> 14 (Traumanurse): Keeping the patient up to date. Telling from patient's perspective what is done and monitoring. Physicians usually examine and go somewhere else to write texts. If there is a remarkable change in the vitals then reporting it. Taking care of treating pain, asking about pain medication.

TABLE 7 Main goals of trauma team members

Anaesthesiologist	Keep patient alive and prevent further damage Make sure patient survives computer tomography (examination)
Surgeon	Keep patient alive Use human resources rationally Do only essential Straightforward and fluent leadership Thoroughly examined patient, make work diagnoses and present to trauma leader in a treatment order
Anaesthesia nurse	Assisting anaesthesiologist to perform actions safely and fluently by providing equipment and materials Monitoring patient Monitoring vital signs
Trauma nurse	Be a one step ahead when assisting surgeon Keep patient informed Make sure patient is thoroughly researched and is painless Monitoring vital signs

5.4 Trauma Team Decision Making Points

Points for decision making are described in table 8. Anaesthesiologists and surgeons seem to make decisions on ABCDE protocol as there is decision for airways (A), breathing (B), circulation (C), disability (D) and exposure (E).

> 6 (Anaesthesiologist): If you think it through ABCDE then knowing what is the patient status. A means airways, is the patient consciousness enough to keep airways open himself or should I do it. What other procedures are supposed to do, if patient needs to be put asleep. Breathing needs to be checked with the surgeon, what is happening. Basic work order is that if there is a pneumo- or hemothorax then the surgeon puts the chest tube and I put air from the other end. Other thing is stability of circulation. Should it be treated with fluids or active, do we need blood products. When thinking about neurology what is the point to secure the airways and on the other hand before putting patient asleep you need to check neurological status in order to minimize surprises later on. And letter E is about taking care of exposure but it is important to remember examining the patient properly.

> 2 (Surgeon): If the patient does not respond normally to normal procedures. What happens now. Do we examine more or enhance treatments or should something else be done what normally isn't done in situation like this. Those treatments in a scenario like this are quite simple which apply in 99.9% of the patients. There needs to be enough drips which working well so that body gets fluids which add blood vessel capacity or if needed blood really quick. Ensuring oxygenation. It happens with a mask or intubation.

To a surgeon in a leader role there are other decisions like need for surgery and level of urgency.

> 1 (Surgeon): At the point when patient comes if using FAST-ultrasound patient's hemodynamics are found unstable the surgeon's decision should lead to going straight to the operating room and nothing else is done. That is one thing. On the other hand if breathing sounds are quiet and patient's breathing collapses then decompressing a tension pneumothorax needs to be done. I would do it primary with a needle if there is no imaging. The next decision making points are based on imaging results. When traumaCT or limbs are imaged a decision is made based on them if patient needs to go to the operating room urgently, not in hasty or if operating room is needed at all or if just a surveillance is enough. In most of the cases surveillance is enough. Imaging is the base for surgeon's decision making in 9 times out of 10. That is the most important thing.

For anaesthesia nurse and trauma nurse the decision making points are the same, they observe vital signs and report the changes to receive further instructions.

> 14 (Traumanurse): ...if blood pressure starts to come down I increase the drip and then I ask if some other fluids are given to support pressure.

TABLE 8 Points for decision making of the trauma team members

Anaesthesiologist	Keeping airways open, intubation Ensuring breathing, need for chest tube Stabilizing blood circulation, blood products
Surgeon	Examination or enhancing treatment Ensuring blood circulation and breathing Need for surgery and level of emergency Possibilities to wait for confirmation to make a procedure Final decisions after scanning
Anaesthesia nurse	Monitoring vitals, stating if something is off balanced, checking in case of error in equipment, asking for further directions if needed and performing those
Trauma nurse	Monitoring vitals, stating if something is off balanced, checking in case of error in equipment, asking for further directions if needed and performing those

5.5 Challenges in Current Information Technology

According to the interviews systems are too massive and confusing. Complexity makes them slow to use and it takes long to get the systems operating. Also using them is difficult because of lack of fluency. Sometimes username and password don't work and you can't log into the system. Connections may also be cut. Need for backup system, amount of wires, need for configuration and incompatibility between different EMR systems are seen as the biggest problems. Looking for an electric wire and a place to plug it in can take time.

> 14 (Trauma nurse): At least all the wires off the monitors. Blood pressure and everything should go wirelessly. It is very challenging when the wires are all over the place and in a mess. That would be the first thing, which would be really great. I think our writing on paper is old fashioned but it works. It is fast and easy.

One respondent hoped to get easily accessible summary page to EMR system telling up-to-date medication, allergies and illnesses. Now the information is scattered on different pages.

> 9 (Anaesthesiologist): It can be that you don't get a full picture from texts. A summary page is missing. Health center page has it and they are diligent. You might find a summary page. But you can't be sure if there is everything. If I want to be sure I look internal medicine, pulmology and neurology pages. I find the most important illnesses from them. If the patient has been at the surgical ward being operated or had fractures they don't necessarily affect patient's general condition. When I open medication page I can quickly detect what illnesses the patient has. If that could be affected that there is no summary page. A page where would be all diagnoses.

Electronic triage form was told to be something that has been tried to develop few years ago but it didn't succeed. Electronic record keeping is still seen as the way things will be done in the future. Maybe some checklist-type guidance could be integrated to help noticing important factors.

> 15 (Trauma nurse): Electronic writing should be easy to use. A program which guides the nurse forward and all the things are done which need to be done regarding that patient. It would not let you go forward certain some values are missing. It would standardize patient treatment because the examining would have a structure. It needs to have a backup system. If information system black out would occur all the forms need to be available for use right away. It has to provide a good report from the patient. Further treatment facility needs to be told clearly what has been done to the patient at the shockroom. Patient safety is an absolute requirement. If there are orders it needs to show clearly if the orders are done.

Today it is considered normal to say out loud what was found to be wrong but it is seen equally important to say out loud also the things that were checked but found to be all right. Solution to support perceiving findings needs to be built the right way so that it does work in a fast paced environment and doesn't control too much the ways to proceed. Too much information is considered to cause bad decisions. There is also a problem with different systems when information is displayed differently and it takes time to find the right information. Especially laboratory results can be found from different places organized differently in multiple systems. One monitor showing at one glimpse the important vital values without some sections being passive on the monitor was proposed as a good solution.

6 DISCUSSION

Research focus was set on studying the information the trauma team needs to be aware of to gain and maintain situation awareness. In this chapter findings answering the research question are discussed. Next implications to theory and practice are presented.

6.1 Research Question

Aim of this research was to discover preliminary requirements for an electronic clinical decision support system, which can help decision making by supporting situation awareness. The research question was:

How situation awareness supports trauma team's decision making in Central Finland Central Hospital?

The situation awareness can support trauma team decision making in Central Finland Central Hospital by providing information needed to keep the patient alive. Decisions relating to this goal are:

- ensuring breathing
- ensuring blood circulation
- monitoring vital signs

The information required to these decisions includes:

- Background information: basic illnesses and medication
- Pre-arrival information: injury energy, injuries and breathing sounds (information about abnormalities)
- When treating: oxygen saturation, blood pressure, heart rate, consciousness and looks

This information is gathered to a model presented in figure 12, which is based on the SA model for anaesthesiologist (Schulz et al., 2013, 8). The model can be used to discover design requirements for a clinical decision support system. This model is built upon car crash situation but it is general in the way that there is not much information needed to make decisions in emergency settings. Few vital signs, injury energy and the looks of the patient are enough for all the trauma team members. Basic illnesses and medication are checked from the background information, which usually is an electronic health record. These things can also be asked straight from the patient. Pre-hospital information tells about injury energy and injuries. Injuries are of course seen straight from the patient when he or she has arrived to the shock room. Breathing sounds are listened straight from the patient. Patient monitor displays oxygen saturation, blood pressure and heart rate. Examining the patient gives an idea of level of consciousness. Just looking at the patient gives a lot of important information to the trauma team. These information elements are enough to launch an idea of possibility for pneumo- or hemothorax. That would result in collapsed lung which in turn would put pressure on blood circulation. Usually imaging is done before making decisions for actions but if fast actions are needed inserting chest tube can be done without imaging. In addition to need for the chest tube there is a need for monitoring equipment. Continuous monitoring of the vital signs is important for staying up to date of patient's wellbeing.

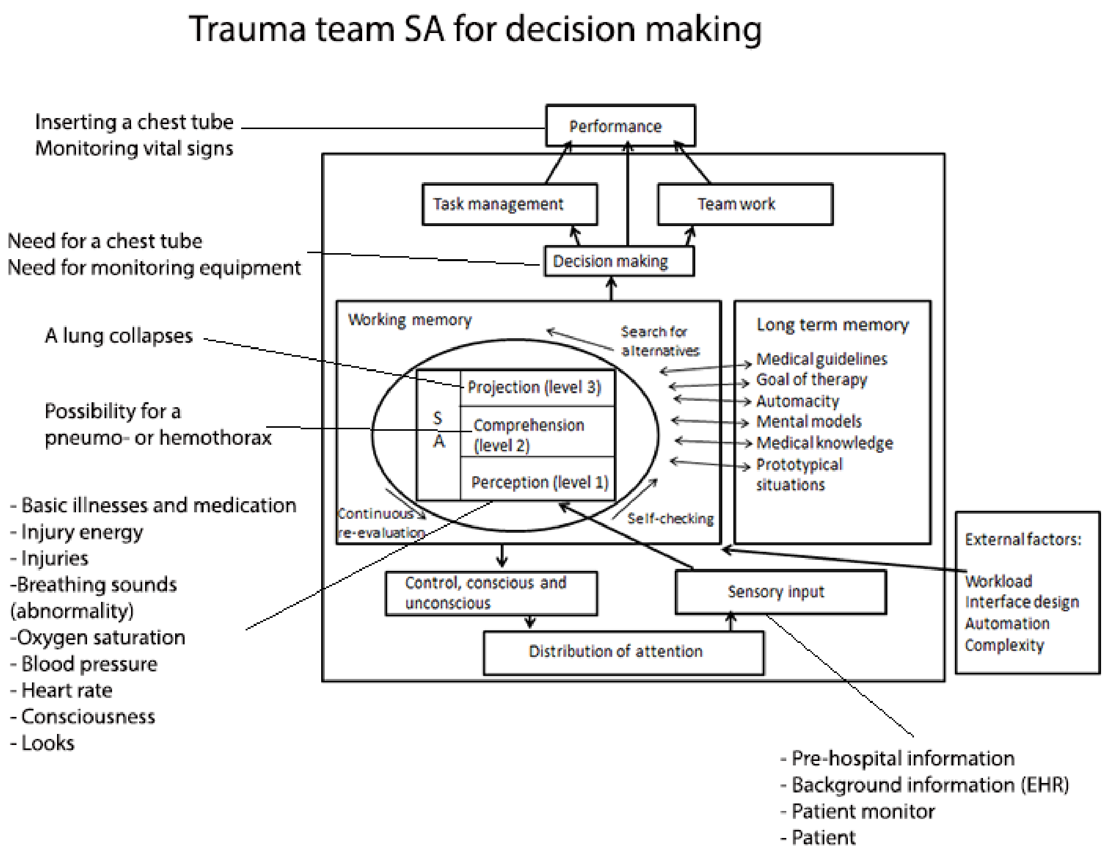

FIGURE 12 Trauma team's situation awareness in the car crash situation based on situation awareness model of Schulz et al. (2011)

6.2 Implications for Research

Described trauma team work and information flow gives insight on what kind of actions take place during trauma resuscitations without concentrating too much on medical aspects. This is seen important because understanding workflow is essential for creating user friendly systems. With a user centered design it is possible to accomplish a system, which is user friendly. As stated earlier in this thesis technology in health care has many advantages. Quality increases and errors decrease but also money is saved according to Militello et al. (2013) and Chaudry et al. (2006). Building a system, which is approved by the users, can have a significant effect.

This thesis provides knowledge for the situation awareness research about the trauma team activities. The trauma team's goals, decisions and information needs are described for gaining and maintaining good situation awareness. The trauma team activities are good surroundings for studying situation awareness in a fast-paced environment where decisions are made quickly. Using different SA measurements for researching ensures that all relevant things are considered. Using a Goal-Directed Task Analysis style method in this study leaves space for more full investigation. With a more detailed study a tree structure could be built to form a basis for Situation Awareness Global Assessment Technique. Because the trauma team is a team the situation awareness requirements need to be studied also at the team level instead of individual roles.

When comparing results with Sarcevic (2007) as primary survey information needs vital signs, airway, breathing sounds, neurological status were important in both results. Pre-hospital information study of Zhang et al. (2013) found mechanism of injury the most important thing with 10 mentions and injuries were mentioned only once. In this study injury energy and breathing were found the most wanted information, injury energy and injuries coming as second. Sarcevic's another study (2012) about identifying information sources match findings in this research. Vital signs monitor is a source for oxygen saturation, heart rate, respitory rate and blood pressure. Looking at the patient gives other information. In Nilsson's (2014) design the vital signs that appear on the screen are pulse, saturation and blood pressure and these help remote expert to have a situation awareness of trauma resuscitation. In this study pulse was not mentioned many times but heart rate instead was. Saturation and blood pressure were important also in this research. Results of this study are in line with other studies of trauma team information needs.

To the field of clinical decision support systems this thesis gives information about supporting trauma team's decision making in a car crash situation. In Fitzgerald's TR&R clinical decision support system (2011) time, pulse, oxygen saturation, blood pressure, ABCDE-protocol and given treatments are presented with pre-hospital information. Results of this study indicate that these information elements are needed to support decision making.

6.3 Implications for Practice

The research brought up several things to information technology development in healthcare surroundings and especially in the shock room. The top challenges were the information systems. They are slow and not fluent to use. Also large amount of wires was a concern. Reducing systems’ complexity and wireless equipment would solve these issues.

Findings of this study can be used to build a decision support system to support situation awareness in other medical situations other than trauma resuscitation of patient from a car crash incident. When thinking about a possible clinical decision support to be built based on this research, there are few things to keep in mind. The right information, to the right person, at the right time, in the right format and through the right channel are the CDS Five Rights described by Sirajuddin et al. (2012, 3). The right information, the right time and the right person were discovered in this thesis.

Moja et al. (2014) presented CDSS characteristics. For trauma team purposes a system with diagnosis and planning or implementing treatment functions are essential to provide accurate diagnosis. Time for the decision support is before patient arrival and at the patient encounter. Presentation type should be automatic but designed in a way that it does help to user instead of confusing. For the trauma team activities all trauma team members need to have access for relevant information for excellent performance. Especially trauma team leader needs to have all relevant information for decision making as he/she is responsible for the situation.

Simple and image based interfaces are the key in designing a mobile interface for a CDSS. In the trauma team activities portability is an important aspect of equipment design. There may be a situation where treating a patient requires a lot of room and equipment needs to be removed from the bedside. These factors were mentioned by Martinez-Perez et al .(2014) and Mickan et al. (2014.)

Usability is a major concern. System needs to fit into user's work flow and not demand user to learn new ways for doing things. Trust in knowledge database is important. If it does not stay up to date the trust for the system decreases. In the field of medicine research is done continuously so the database needs to be updated frequently. Situation awareness demons need to also be considered in developing a system to make it as user friendly as possible. Attentional tunneling, requisite memory trap, workload and other stressors, data overload, misplaced salience, complexity creep, errant mental models and out-of-the loop syndrome, described by Endsley and Jones (2012), are things to think about when trying to avoid confusing the user. With a user friendly system, which user really like to use and think is trustworthy, impact of clinical decision support system on performance will improve.

7 CONCLUSIONS

Conclusions are presented in this chapter. First there is a short summary of the thesis. Then contributions are discussed and limitations acknowledged. Future research topics are presented in the last section.

7.1 Summary

Aim of this study was to find out how clinical decision support systems can support situation awareness in Trauma Team decision making in Central Finland Central Hospital. To answer this question research focus was set on finding out what information the trauma team needs to be aware of to gain and maintain situation awareness. At this moment trauma team does not have an electronic decision support system in use. The scribing nurse gathers information to a paper form (see appendixes 2 and 3). Other team members usually rely on their memory even though it is possible to ask previous markings from the scribing nurse.

A qualitative case study was performed for updating the situation awareness model of Schulz et al. (2013, 8). First 8 trauma team exercise video recordings were observed and recorded debriefings were transcribed. These actions provided basis for interview questions. Five surgeons, four anaesthesiologists, three trauma nurses and three anaesthesia nurses were individually interviewed in a semi structural manner for a half an hour. After transcribing and analyzing interview recordings, a matrix was built based on information elements mentioned in the interviews. Recurring pieces of information were applied to the situation awareness model with decisions. Trauma team goal is to keep the patient alive. Ensuring breathing and blood circulation and monitoring vital signs are decisions associated with this goal. The information elements answer to the information needs of these decisions. These information elements are basic illnesses and medication, injury energy, injuries, information about abnormalities (breathing sounds), oxygen saturation, blood pressure, heart rate, consciousness and looks. The modified model presents preliminary requirements for a clinical decision support system, which supports situation awareness of trauma team members.

7.2 Contributions

This thesis brings useful information to the areas of situation awareness in trauma team activities, clinical decision support systems and information technology in health care.

Situation awareness theory was successfully applied to this case study. The situation awareness model was further developed according to the findings from the car crash trauma resuscitation simulation. The modified situation awareness model can be used to develop a more profound requirement analysis of the trauma resuscitation. At this point it is a preliminary version due to limitations of the thesis.

Taking situation awareness into account in system design makes it possible to have a user friendly CDS system. As described earlier in the text, physicians want the system to be user friendly and support the workflow. The ideal trauma team work flow according to respondents was also presented. This study confirms the earlier studied information needs of the trauma team members in the trauma resuscitation situations. There are not many different elements to support decision making in the trauma resuscitation.

Other information technology solutions to health care domain can get development ideas from the current challenges presented.

7.3 Limitations

Limitations to this study are mainly related to fact that writer is a non-medical person and the studied case and people are medical. Different mental schemas are difficult to take into account. Inexperienced interviewer can have impact on the results.

Even though interviews were done in Finnish and the questions were simple, there is an opportunity for misunderstandings. Quotes from the interviews were carefully translated but there is a chance to for some information to get lost in translation. English medical vocabulary was a challenge especially when the writer was not familiar with medical language in Finnish. Information technology related questions were easy for the interviewer but the interviewees might have found them difficult. There was a difficulty with translating the term situation awareness to Finnish because the used dictionaries do not include the term. A term situation sense is therefore mentioned in the interview questions as an alternative for the situation awareness term.

Due to various reasons the interview process was delayed until July and August, which are the common months for the summer holiday. Nevertheless, the study had a good participant rate.

The interviews were semi structured and that gave an opportunity for the both sides to ask further questions if the initial response was difficult to understand. Interview technique made possible to stray from the planned questions. This was considered to be useful when the topic of the conversation stayed in the area of information technology in health care.

In this study the same patient case was told to every respondent. Generalization of the results can be a problem because patient cases are unique. But on the other hand there is only a limited amount of the vital values which are important when treating a patient.

In the matrix vitals were presented as a whole and then separated. This was because interviewed trauma nurses mentioned only "vitals" but did not specify what physiological measures they meant. The matrix would stay quite the same even if the meant separate values were known.

There could be different results from the interviews if questions were posed from other aspect. Instead of asking what information respondents need, the question could have been who doesn't need the information like the laboratory tests or vitals.

If there were more resources to this thesis, it would have been interesting to watch the trauma team car crash simulation exercise again to check if the responses in the interviews were in line with the actions in the simulation.

When comparing pre-hospital information provided in the interviews and the pre-hospital information trauma team members consider important it is seen that injury related information and breathing sounds were the important things. It is probable that vital signs were not mentioned by more people because they were in the normal range.

7.4 Future Research

There are many possibilities for future research. As this thesis is a preliminary research to a CDSS to support the trauma team activities, continuing to develop a new system is one option. Existing systems could also be developed to better meet users' expectations based on the results.

When thinking about developing an information technology solution to better meet the trauma team needs it is important to notice different needs of different roles. The trauma team leader leads the situation from the sidelines if there are enough personnel doing the examination. The leader could benefit from a portable device which has an interface for an electronic clinical decision support system. At the moment there isn't such a system.

All relevant information from the patient should be available in real-time. As a decision support system the system should provide assistance in decision making. This usually happens by entering information and the system coming up with possible solutions. There needs to be an efficient computer that can go through data to find solutions for a given trauma situation. An interesting option would be studying how Watson could be used for this.

A possibility of wearable technology like Google Glass could provide an alternative for vital signs monitor or at least offer to support to it. When having eyes on the patient glancing to the monitor can be difficult. Seeing the relevant information without taking your eyes of the patient is an interesting research option. This can also effect on scribing.

A big electronic display situated outside the shock room would help those who arrive late to gain situation awareness of the patients being treated.

Regarding a system design with situation awareness aspect, a SAGAT technique could be used to get a more profound understanding of trauma team's decision support needs. Also eye tracking devices could be used for researching what is the information the team members are looking for.

A decision support system can be a non-electric solution. Therefore studying different paper forms as alternatives for electronic systems can have value. In a high impact and quick decision making system availability is an important issue.

REFERENCES

Alsos, O. A. (2010). Awareness and usability issues in clinical CSCW systems. In *The 2010 ACM Conference on Computer Supported Cooperative Work*, (pp. 501-502). Savannah, Georgia, February 6–10, 2010.

Arnott, D. R., & Dodson, G. (2008). Decision support systems failure. In Burstein, F. & Holsapple, C. W. (Eds.), Handbook on decision support systems (Vol. 1, pp. 763-790). Berlin: Springer.

Bates, D. W., Kuperman, G. J., Wang, S., Gandhi, T., Kittler, A., Volk, L., & Middleton, B. (2003). Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. *Journal of the American Medical Informatics Association*, 10(6), 523-530.

Buntin, M. B., Burke, M. F., Hoaglin, M. C., & Blumenthal, D. (2011). The benefits of health information technology: a review of the recent literature shows predominantly positive results. *Health affairs*, 30(3), 464-471.

Chaudhry, B., Wang, J., Wu, S., Maglione, M., Mojica, W., Roth, E., ... & Shekelle, P. G. (2006). Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Annals of Internal Medicine*, 144(10), 742-752.

Cooper, S., Porter, J., & Peach, L. (2014). Measuring situation awareness in emergency settings: a systematic review of tools and outcomes. *Open Access Emergency Medicine*, 6, 1–7.

Duodecim Medical Publications Ltd. (2012). EBMeDS White Paper. Accessed 17.10.2014. http://www.ebmeds.org/www/EBMeDS%20White%20Paper.pdf

Endsley, M. R. (2000). Theoretical underpinnings of situation awareness: A critical review. In Endsley, M.R. & Garland, D. J. (Eds.), Situation awareness analysis and measurement. (pp. 3-32.) Mahwah, NJ: LEA.

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 37(1), 32-64.

Endsley, M. R. (1988). Design and evaluation for situation awareness enhancement. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* Vol. 32, No. 2, (pp. 97-101). SAGE Publications.

Endsley, M. R., Jones D. G. (2012). *Designing for situation awareness: An approach to user-centered design*. (2nd edition) Boca Raton, FL: CRC Press.

Fitzgerald, M., Cameron, P., Mackenzie, C., Farrow, N., Scicluna, P., Gocentas, R., & Rosenfeld, J. V. (2011). Trauma resuscitation errors and computer-assisted decision support. *Archives of Surgery*, *146*(2), 218–225.

Fitzgerald M, Farrow N, Scicluna P, Murray, A., Xiao, Y., & Mackenzie, C. F. (2008). Challenges to Real-Time Decision Support in Health Care. In Henriksen K, Battles JB, Keyes MA, et al., (Eds), *Advances in Patient Safety: New Directions and Alternative Approaches (Vol. 2: Culture and Redesign).* Rockville (MD): Agency for Healthcare Research and Quality (US).

Gaba, D. M., Howard, S. K., & Small, S. D. (1995). Situation awareness in anesthesiology. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 37(1), 20-31.

Garg, A. X., Adhikari, N. K., McDonald, H., Rosas-Arellano, M. P., Devereaux, P. J., Beyene, J., ... & Haynes, R. B. (2005). Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. *Jama*, 293(10), 1223-1238.

Heselmans, A., Van de Velde, S., Donceel, P., Aertgeerts, B., & Ramaekers, D. (2009). Effectiveness of electronic guideline-based implementation systems in ambulatory care settings-a systematic review. *Implement Science*, 4(82).

Hunt, D. L., Haynes, R. B., Hanna, S. E., & Smith, K. (1998). Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. *Jama*, *280*(15), 1339–1346.

Horsky, J., Schiff, G. D., Johnston, D., Mercincavage, L., Bell, D., & Middleton, B. (2012). Interface design principles for usable decision support: a targeted review of best practices for clinical prescribing interventions. *Journal of biomedical informatics*, *45*(6), 1202–1216.

Hosack, B., Hall, D., Paradice, D., & Courtney, J. F. (2012). A look toward the future: decision support systems research is alive and well. *Journal of the Association for Information Systems*, 13(5), 3.

IBM Corporation. 2014. IBM Case studies, Wellpoint, Inc. Accessed 16.1.2015 http://www-01.ibm.com/common/ssi/cgibin/ssialias?subtype=AB&infotype=PM&appname=SWGE_IM_DD_USEN&htmlfid=IMC14792USEN&attachment=IMC14792USEN.PDF#loaded

Jalote-Parmar, A., & Badke-Schaub, P. (2010). Situation awareness in medical visualization to support surgical decision making. In *Proceedings of the 28th Annual European Conference on Cognitive Ergonomics* (pp. 201-208). ACM.

Jaspers, M. W., Smeulers, M., Vermeulen, H., & Peute, L. W. (2011). Effects of clinical decision-support systems on practitioner performance and patient outcomes: a synthesis of high-quality systematic review findings. *Journal of the American Medical Informatics Association*, *18*(3), 327–334.

Jones, D. G., & Endsley, M. R. (1996). Sources of situation awareness errors in aviation. *Aviation, Space, and Environmental Medicine*. 67(6), 507-512

Jones, S. S., Rudin, R. S., Perry, T., & Shekelle, P. G. (2014). Health information technology: an updated systematic review with a focus on meaningful use. *Annals of Internal Medicine*, 160(1), 48-54.

Kawamoto, K., Houlihan, C. A., Balas, E. A., & Lobach, D. F. (2005). Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *Bmj*, 330(7494), 765.

Keski-Suomen sairaanhoitopiiri. (2014). Sairaanhoitopiirin esittelydiat. Accessed 11.1.2015.
http://www.ksshp.fi/fi-FI/Sairaanhoitopiiri/Viestinta/Ksshpn_materiaalit

Keski-Suomen sairaanhoitopiiri. n.d. Pre-information form.

Keski-Suomen sairaanhoitopiiri. n.d. Triage form.

Khalifa, M. (2014). Clinical Decision Support: Strategies for Success. *Procedia Computer Science*, *37*, 422–427.

Klein, G. (2000). Analysis of situation awareness from critical incident reports. In Endsley, M. R., & Garland, D. J. (Eds.), *Situation awareness analysis and measurement.* (pp. 45–63). Mahwah, NJ: Lawrence Erlbaum Associates.

Kortteisto, T. (2014). Neuvova potilaskertomus-käyttö ja vaikutus potilaan hoitoon. Doctoral thesis in Health Economics. Tampere: University of Tampere.

Kusunoki, D. S., Sarcevic, A., Weibel, N., Marsic, I., Zhang, Z., Tuveson, G., Burd, R. S. (2014a.) Balancing design tensions: Iterative display design to support ad hoc and interdisciplinary medical teamwork. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems (CHI 2014)*, pp. 3777-3786. Toronto, Canada, April 26 – May 1, 2014.

Kusunoki, D., Sarcevic, A., Zhang, Z., & Yala, M. (2014b.) Sketching Awareness: A Participatory Study to Elicit Designs for Supporting Ad Hoc Emergency Medical Teamwork. *Computer Supported Cooperative Work (CSCW)*, 1-38.

Lee, H. (2014). Paging Dr. Watson: IBM's Watson supercomputer now being used in healthcare. *Journal of AHIMA/American Health Information Management Association*, 85(5), 44-47.

Martínez-Pérez, B., de la Torre-Díez, I., López-Coronado, M., Sainz-de-Abajo, B., Robles, M., & García-Gómez, J. M. (2014). Mobile clinical decision support systems and applications: a literature and commercial review. *Journal of Medical Systems*, 38(1), 1-10.

Mickan, S., Atherton, H., Roberts, N. W., Heneghan, C., & Tilson, J. K. (2014). Use of handheld computers in clinical practice: a systematic review. *BMC medical informatics and decision making*, *14*(1), 56.

Militello, L. G., Arbuckle, N. B., Saleem, J. J., Patterson, E., Flanagan, M., Haggstrom, D., & Doebbeling, B. N. (2014). Sources of variation in primary care clinical workflow: Implications for the design of cognitive support. *Health Informatics Journal*, 20(1), 35-49.

Moja, L., Kwag, K. H., Lytras, T., Bertizzolo, L., Brandt, L., Pecoraro, V., ... & Bonovas, S. (2014). Effectiveness of Computerized Decision Support Systems Linked to Electronic Health Records: A Systematic Review and Meta-Analysis. *American Journal of Public Health*, 104(12), e12–e22.

Musen, M. A., Middleton, B., & Greenes, R. A. (2014). Clinical decision-support systems. In Shortliffe, E. H., Cimino, J. J. (Eds.), *Biomedical informatics, 4th edition.* (pp. 643–674). Springer London.

Nilsson, M. (2014). Mediated and Mobile Communication for Experts. Doctoral thesis in Media Technology and Interaction Design. Stockholm: KTH Royal Institute of Technology.

Parush, A., Kramer, C., Foster-Hunt, T., Momtahan, K., Hunter, A., & Sohmer, B. (2011). Communication and team situation awareness in the OR: Implications for augmentative information display. *Journal of biomedical informatics*, *44*(3), 477–485.

Romano, M. J., & Stafford, R. S. (2011). Electronic health records and clinical decision support systems: impact on national ambulatory care quality. *Archives of Internal Medicine*, 171(10), 897–903.

Salfinger, A., Retschitzegger, W., & Schwinger, W. (2013). Maintaining Situation Awareness over Time--A Survey on the Evolution Support of Situation Awareness Systems. In *Technologies and Applications of Artificial Intelligence (TAAI), 2013 Conference on* (pp. 274-281). IEEE.

Sarcevic, A., Weibel, N., Hollan, J. D., & Burd, R. S. (2011). TraumaPen: A Paper-Digital Interface for Information Capture and Display in Time-Critical Medical Settings. Technical Report.

Sarcevic, A. (2007). Human - information interaction in time - critical settings: Information needs and use in the emergency room. *Proceedings of the American Society for Information Science and Technology*, 44(1), 1-15.

Sarcevic, A., & Burd, R. S. (2008). "What's the Story?" Information Needs of Trauma Teams. In *AMIA Annual Symposium Proceedings*. Vol. 2008, p. 641. American Medical Informatics Association.

Sarcevic, A., Marsic, I., Lesk, M. E., & Burd, R. S. (2008). Transactive memory in trauma resuscitation. In *Proceedings of the 2008 ACM conference on Computer supported cooperative work* (pp. 215-224). ACM.

Sarcevic, A., & Burd, R. S. (2009). Information handover in time-critical work. In *Proceedings of the ACM 2009 international conference on Supporting group work* (pp. 301-310). ACM.

Sarcevic, A., Zhang, Z., & Kusunoki, D. S. (2012). Decision making tasks in time-critical medical settings. In *Proceedings of the 17th ACM international conference on Supporting group work* (pp. 99-102). ACM.

Shibl, R., Lawley, M., & Debuse, J. (2013). Factors influencing decision support system acceptance. *Decision Support Systems*, *54*(2), 953–961.

Shim, J. P., Warkentin, M., Courtney, J. F., Power, D. J., Sharda, R., & Carlsson, C. (2002). Past, present, and future of decision support technology. *Decision support systems*, 33(2), 111-126.

Schulz, C. M., Endsley, M. R., Kochs, E. F., Gelb, A. W., & Wagner, K. J. (2013). Situation awareness in anesthesia: concept and research. *Anesthesiology*, 118(3), 729-742.

Sirajuddin, A. M., Osheroff, J. A., Sittig, D. F., Chuo, J., Velasco, F., & Collins, D. A. (2009). Implementation pearls from a new guidebook on improving medication use and outcomes with clinical decision support: effective CDS is essential for addressing healthcare performance improvement imperatives. *Journal of Healthcare Information Management*, *23*(4), 38.

Sittig, D. F., Wright, A., Osheroff, J. A., Middleton, B., Teich, J. M., Ash, J. S., ... & Bates, D. W. (2008). Grand challenges in clinical decision support. *Journal of biomedical informatics*, *41*(2), 387–392.

Trauma.org. n.d. The Trauma Team. Accessed 9.2.2015. http://www.trauma.org/archive/resus/traumateam.htm

Vannucci, A., & Kras, J. F. (2013). Decision Making, Situation Awareness, and Communication Skills in the Operating Room. *International Anesthesiology Clinics*, 51(1), 105-127.

Williams, B., Quested, A., & Cooper, S. (2013). Can eye-tracking technology improve situational awareness in paramedic clinical education?. *Open Access Emergency Medicine [E]*, 5, 23–28.

Wright, A., Sittig, D. F., Ash, J. S., Sharma, S., Pang, J. E., & Middleton, B. (2009). Clinical decision support capabilities of commercially-available clinical information systems. *Journal of the American Medical Informatics Association*,*16*(5), 637–644.

Wright, M. C., Taekman, J. M., & Endsley, M. R. (2004). Objective measures of situation awareness in a simulated medical environment. *Quality and Safety in Health Care*, *13*(suppl 1), i65–i71.

Wu, T., Dameff, C., & Tully, J. (2014). Integrating Google Glass into simulation-based training: experiences and future directions. *Journal of Biomedical Graphics and Computing*, 4(2), p49.

Zhang, Z., Sarcevic, A., & Burd, R. S. (2013). Supporting Information Use and Retention of Pre-Hospital Information during Trauma Resuscitation: A Qualitative Study of Pre-Hospital Communications and Information Needs. In *AMIA Annual Symposium Proceedings* (Vol. 2013, p. 1579). American Medical Informatics Association.

Yet, B., Perkins, Z. B., Rasmussen, T. E., Tai, N. R., & Marsh, D. W. R. (2014). Combining data and meta-analysis to build Bayesian networks for clinical decision support. *Journal of Biomedical Informatics*, 52, 373-385.

Yngling A., Nilsson M., Groth K. n.d. Measuring Shared Situational Awareness at a Swedish trauma centre. BISL. Accessed 27.10.2014. https://www.kth.se/social/upload/5196327df276543ceebde159/Yngling_paper.pdf

Yao, W., & Kumar, A. (2013). CONFlexFlow: Integrating flexible clinical pathways into clinical decision support systems using context and rules. *Decision Support Systems*, 55(2), 499-515.

APPENDIX 1 PRE-INFORMARTION FORM

ENNAKKOILMOITUSLOMAKE

ILMOITTAJA: ____________________

POTILAAN NIMI: ____________________ SOTU: ____________

MITÄ ON TAPAHTUNUT:

____
____
____
____
____

OIREET ALKANEET: ____________________ MAREVAN: KYLLÄ ☐

NÄHTY LIIKKEELLÄ: ____________________ EI ☐

HENGITYS	VERENKIERTO	TAJUNTA
SPONT. HENGITYS ☐ INTUBOITU ☐ CPAP ☐ SaO_2 ________ HF ______ krt/min	RR ________ PULSSI ________ HEMODYNAMIIKKA VAKAA ☐ EPÄVAKAA ☐	TAJUISSAAN ☐ TAJUTON ☐ SEKAVA / UNELIAS ☐ PUPILLAERO ☐

GCS

SILMIEN AVAUS	PUHE	LIIKE	RAAJAVOIMA
4. SPONTAANI	5. ORIENTOITUNUT	6. NOUDATTAA KÄSKYJÄ	++ NORMAALI
3. KÄSKYSTÄ	4. SEKAVA	5. PAIKANTAA KIVUN	+ HIEMAN HEIKKO
2. KIVUSTA	3. YKSITTÄISIÄ SANOJA	4. VÄISTÄÄ KIVUN	- HYVIN HEIKKO
1. EI AVAA	2. ÄÄNTELYÄ	3. FLEKSOI KIVUN	
	1. EI PUHETTA	2. EKSTENSOI KIVUN	
		1. EI VASTETTA	

LÄÄKEHOITO

____
____
____

ENNAKKOILMOITUS TEHTY PVM ____________ KLO ________

ARVIOITU SAAPUMISAIKA: ____________________

TIEDOT VASTAANOTTI ____________________

ILMOITETTU: ☐ LÄÄKÄRI ☐ HOITOTIIMI ☐ KIERTOHOITAJA ☐ LABRA ☐ RTG ☐ CT ☐ ANE LÄÄK. ☐ LS

HUOM! LÄÄKÄRI SOITTAA RADIOLOGILLE

(Keski-Suomen sairaanhoitopiiri, n.d.)

APPENDIX 2 TRIAGE FORM, PAGE 1

Nimitarra	**Pvm/aika** **Paikka** **Tulo-oire**

Toimintakyky [ ] Lapsi<7v [ ] Omatoiminen
[ ] Tarvitsee vähän apua [ ] Tarvitsee paljon apua
[ ] Täysin muiden avusta riippuvainen

Ilmatiet	**Hengitys**	**Pulssi**	**Tajunta GCS**	**Pupillat**	**Kipu VAS**
[ ] auki	[ ] normaali	[ ] normaali	[ ] 15-13	[ ] ok	[ ] 0
[ ] uhka	[ ] ahdistaa	[ ] takykardinen	[ ] 12-9	[ ] Puoli-ero	[ ] 1-2
[ ] ilmatietukos	[ ] hyperventiloi	[ ] bradykardinen	[ ] alle 8		[ ] 3-5
	[ ] hengityskatkoja	[ ] epätasainen			[ ] 6-8
					[ ] 9-10

Triageluokka A B C D E
[ ] **Erikoissairaanhoito** [ ] **Perusterveydenhuolto** [ ] **Kontrollikäynti**
OPER [ ] KIR [ ] KNK [ ] SIL [ ] GYN [ ] LASTENTAUDIT
KONS [ ] SIS [ ] NEUR [ ] KEU [ ] ONK [ ] PSYK [ ] **Muu**________

Paino **Syönyt** **Allergia** [ ] Ei tiedossa
[ ] KYLLÄ, mille____________________
Pituus **Juonut**

Lastensuojeluilmoitus
[ ] Tehty, kuka? [ ] Onko lapsi sijaishuollossa?
[ ] Taloudessa asuu alaikäisiä lapsia? Hoidossa, missä?

Muuta lisätietoa

Triagehoitaja nimi:

Aika	AMB								
RR									
P									
Rytmi									
Lämpö									
HF									
Sat									
CO2									
O2									
GM									
Etyyli									
Diureesi									
VAS									
Silmät									
Puhe									
Liike									

GCS	**Silmien avaus**	**Puhe**	**Liike**	**Raajavoima**
	4 Spontaani	5 Orientoitunut	6 Noudattaa käskyjä	++ Normaali
	3 Käskystä	4 Sekava	5 Paikantaa kivun	+ Hieman heikko
	2 Kivusta	3 Yksittäisiä sanoja	4 Väistää kivun	- Hyvin heikko
	1 Ei avaa	2 Ääntelyä	3 Fleksoi kivun	
		1 Ei puhetta	2 Ekstensoi kivulle	
			1 Ei vastetta	

Raajavoima oik								
Raajavoima vas								

Omaiset / yhteyshenkilö	**Omaisuus**	**Vaatteet**
[ ] Tarkistettu	[ ] Ei mukana	[ ] Ei mukana
[ ] Ei tiedä	[ ] Omainen viennyt	[ ] Omainen viennyt
[ ] Tietää	[ ] Luetteloitu	[ ] Luetteloitu
[ ] Ei tavoitettu	**Apuvälineet**	[ ] Leikattu

(Keski-Suomen sairaanhoitopiiri, n.d.)

APPENDIX 3 TRIAGE FORM, PAGE 4

Lääkäri: Hoitaja:

Infuusiot Lääkkeet Verituotteet

Klo:

Nimitarra

Potilaan seuranta, hoitotoimenpiteet. Hoidon ja lääkityksen vaste

Klo:

Tutkimukset

Klo:

(Keski-Suomen sairaanhoitopiiri, n.d.)

APPENDIX 4 INTERVIEW QUESTIONS IN FINNISH

Taustatiedot:

- rooli traumatiimissä
- työkokemus terveydenhuollossa
- työkokemus traumatiimissä

Varsinaiset kysymykset:

- Kuvaile lyhyesti ideaaliprosessi alkaen traumahälytyksestä ja päättyen potilaan siirtämiseen pois shokkihuoneesta
- Mikä on päätavoitteesi?
- Mitä alatavoitteita päätavoitteen saavuttamiseen liittyy?
- Mitkä on päätöksenteon kipupisteet?
- Mitä päätöksiä liittyy alatavoitteisiin?
- Mitä tietoa tarvitset päätöksen tekemiseksi?
- Minkä vuoksi tarvitset tietoa?
- Miten tieto auttaa saavuttamaan tavoitteen?
- Mikä on kaikkein mieleenpainuvin komplikaatiotilanne?
- Oliko silloin joku tieto ollut väärin?
- Mikä asia on traumatiimin toiminnassa parhaiten järjestetty? Miksi?

Lisäkysymyksiä:

- Mikä on kriittistä tietoa?
- Mitkä ovat oman kokemuksen mukaan keskeisimmät riskit?
- Miten reaaliprosessi eroaa ideaaliprosessista?
- Mitä yleensä jätetään huomioimatta?
- Mitä tietoa olisi tarvittu, jotta tilanne olisi mennyt paremmin?
- Millaisen esimerkin voit kertoa henkilöstä, jolla on hyvä tilannetaju?