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# The Use of Novel Information Technology in Military Medicine and Mass Casualty Situation Training

ACADEMIC DISSERTATION
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# ABSTRACT

In developed countries, novel information technologies have become an essential part of education in the modern healthcare field. However, using these expensive and continuously developing technologies is often a challenge both for trainers and for students. In military medicine, as a part of national healthcare services, there are special needs for this kind of technology, especially when optimising first aid and initial treatment in challenging field situations. The purpose of this thesis was to study the use of novel information mobile technologies in the training of military medicine for mass casualty situations. Methods chosen were short video clips, the mobile medical information system (IS) and radio frequency identification technology (RFID).

Short video clips are potentially applicable as educational material in teaching advanced airway management and as the first means of introducing the use of a laryngeal tube (LT) or an intubating laryngeal mask (ILMA) to inexperienced military first-responder trainees with no prior hands-on experience. In a study, sixty medical non-commissioned officers were randomly assigned into one of two groups: the LT- and the ILMA-group. After viewing the video clips, the trainees were required to perform 10 consecutive, successful insertions of the given instrument into a mannequin. The goal of 10 consecutive successful insertions was attained by all 30 subjects in the LT-group, and by 27 of 29 subjects in the ILMA-group with a maximum of 30 attempts. "Satisfactory" to "good" skill levels can be achieved with the applied video-clip demonstration method, even in inexperienced first-responder trainees lacking previous hands-on experience. Self-assessment measured by the VAS score showed that the performance was perceived as relatively easy.

A mobile medical information system (IS) was compared between civilian medical students and physicians undergoing compulsory military service in Finland. Special emphasis was placed on differences in system usage and perceptions towards the mobile medical IS. Other points of interest were the important features of the mobile medical system, advantages and disadvantages of using the system in actual emergency situations and use of the device to search for general information. A questionnaire was handed to both sixth-year medical students at the University of Oulu, as well to medical students of a similar academic level undergoing their military service. The two groups were found to

have similar approaches towards the mobile system in different contexts. The results have helped to develop an understanding of how the two groups of users employ a mobile medical information system while also providing insight into some behavioural differences between them. Not all of the differences were significant, indicating the possibility of developing a universal tool for both military and with some civilian application, but with supplemental content in military medicine for military medical officers (MO). When reporting on the possibility of the development of a universal tool for both military and civilian use, MO`s said that they would have liked to complement the mobile medical information system with military medical data.

The applicability of radio frequency identification (RFID) technology and commercial cellular networks designed to provide an online triage system for handling civilian mass casualty situations was tested during a military field exercise. The system proved to be viable. Compared to the current system in use, it dramatically improved the general view of mass casualty situations and enhances medical emergency readiness in this military medical setting. The system can be adapted without any difficulties by the civilian sector for the management of disasters. The feasibility and the direct benefits of the system were evaluated in two separate, simulated civilian mass-casualty situations: one in Finland involving a passenger ship accident and another at a major airport in Sweden with a plane crash scenario. Both simulations involved multiple authorities and functioned as a test setting for comparing the disaster management's situational awareness using the RFID -based system, where triage was done using both a mobile phone system with information sent automatically to the situation command center and the hospital, alongside a traditional method using paper triage tags. The development of situational awareness could be measured directly by comparing the availability of up-to date information at different points in the care chain with both systems. The RFID system proved easy to use, quick and stabile, and significantly improved situational awareness for disaster management. Information about the numbers and status of casualties was available for the coordinating units more than an hour earlier in comparison to the traditional method. Results surpassed the traditional systems in all respects. They also dramatically improved the general view of mass casualty situations and enhanced medical emergency readiness in a multi-organisational medical setting.

The novel information technologies addressed here are of great value both pedagogically and technically in medical training in military medicine and in mass casualty situations.

# TIIVISTELMÄ

Tietotekniikasta on tullut kehittyneissä maissa keskeinen osa terveydenhuollon opetusta ja koulutusta sekä terveydenhuollon palveluja. Kuitenkin uuden tietotekniikan käyttö on usein haasteellista sekä kouluttajille ja opiskelijoille. Sotilaslääketiede on osa kansallista terveydenhuollon järjestelmää, jossa tällaista tekniikkaa varten on eritystarpeita, kun kehitetään ensiavun ja ensihoidon opetusta kliinisesti vaativissa tilanteissa. Tässä väitöskirjatyössä oli tarkoitus tutkia uuden mobiiliteknologian käyttöä sotilaslääketieteen ja suuronnettomuustilanteiden koulutuksessa. Tutkimukseen oli valittu seuraavat uudet informaatioteknologiat: lyhyet videoleikkeet (multimedia), mobiilit lääketieteen tietokannat ja RFID -teknologia (radio frequency identification), (radiotaajuinen etätunnistus). Tässä tutkimuksessa kokeiltiin lyhyttä videoleikettä hengityksen turvaamisen opetuksessa. Tutkimuksessa olivat käytössä kurkunpääputki (LT) tai kurkunpäämaski (ILMA), kun koulutettavina olivat sotilaat, joilla ei ollut aikaisempaa koulutusta tai käytännön kokemusta aiheesta. Lääkintäaliupseerikurssin oppilaat (N=60) satunnaistettiin käyttämään joko kurkunpääputkea (LT), n=30 tai kurkunpäämaskia (ILMA), n=30. Kurkunpääputken (LT) sai paikoilleen 100 % ja kurkunpäämaskin (ILMA) 93,1 % onnistuneesti 10 kertaa peräkkäin. Keskimäärin ensimmäinen onnistunut suoritus kesti hieman yli 20 sekuntia kummallakin menetelmällä ja 10 suorituksen keskiarvo oli hieman yli 10 sekuntia. Kokemattomat ja kouluttamattomat lääkintäaliupseerikurssin oppilaat voivat oppia lyhyen videoleikkeen avulla varmistamaan hengitystiet kurkunpääputkella (LT) tai kurkunpäänaamarilla (ILMA) simuloidussa tilanteessa. VAS -asteikolla mitattu itsearvio varmisti, että suoritus koettiin helpoksi.

Mobiilia lääketieteen tietojärjestelmää ja sen käyttöä verrattiin lääketieteen opiskelijoiden ja varusmiespalvelustaan suorittavien lääkäreiden kesken. Varusmiespalvelustaan suorittavat lääkärit ja lääketieteen opiskelijat saivat käyttönsä kommunikaattorin. Tutkimuksessa selvitettiin, miten nämä kaksi ryhmää eroavat järjestelmän käyttäjinä ja kysyttiin heidän mielipiteitään ja käsityksiään mobiilin lääketieteen tietojärjestelmän käytöstä koulutuksessa. Tutkimuksessa haluttiin selvittää heidän tärkeinä pitämiään ominaisuuksia järjestelmän eduista ja haitoista. Tutkimuksessa haluttiin selvittää, että voidaanko järjestelmän avulla todellisessa hätätilanteessa hakea lääketieteellistä tietoa. Tutkimuksen alussa kuudennen vuosikurssin lääketieteen opiskelijat ja varusmiespalvelus-

taan suorittavat lääkärit vastasivat kyselyyn. Varusmiespalvelustaan suorittavat lääkärit vastasivat kyselyyn uudelleen sen jälkeen, kun he olivat käyttäneet mobiilia lääketieteellistä tietojärjestelmää on noin kolme kuukauden ajan.

Tämä tutkimus on auttanut ymmärtämään sitä, miten nämä kaksi ryhmää käyttävät mobiilia lääketieteellistä tietojärjestelmää ja samalla se tarjosi oivalluksia joihinkin pedagogisiin eroihin näiden kahden ryhmän välillä. Ryhmien väliset erot eivät olleet tilastollisesti merkitseviä. Kerrottaessa mahdollisuudesta kehittää heille universaali väline sekä sotilas- että siviilikäyttöön, kertoivat varusmiespalvelustaan suorittavat lääkärit, että he olisivat halunneet täydentää mobiilia lääketieteen tietojärjestelmää sotilaslääketieteellisillä tiedoilla.

Radio frequency identification (RFID) -teknologian ja kaupallisen matkaviestintäverkon soveltuvuutta potilastietojen käsittelyyn testattiin simuloidussa sotaharjoituksessa. Tutkimuksissa RFID -järjestelmä osoittautui toimivaksi. Verrattaessa järjestelmää tällä hetkellä käytettävään järjestelmään se paransi ratkaisevasti lääkinnällisen pelastustoiminnan valmiutta. Järjestelmä voidaan mukauttaa ilman vaikeuksia siviilialan suuronnettomuus- ja katastrofitilanteiden hallintaan. Testattu järjestelmä toteutettiin kaupallisesti saatavilla olevalla teknologialla (RFID ja matkapuhelinteknologia).

Järjestelmän suoria hyötyjä ja sen toistettavuutta verrattiin suuronnettomuudessa käytettäviin paperisiin potilasluokittelukortteihin kahdessa erillisessä simuloidussa suuronnettomuustilanteessa Suomessa ja Ruotsissa. Molemmissa oli mukana monia viranomaistahoja. RFID -pohjainen järjestelmä, jossa potilaat luokiteltiin kiireellisyysluokkiin (triage) käyttämällä matkapuhelinjärjestelmää lähetti välittömästi automaattisesti tilannetiedon harjoituksen johtoon ja sairaalaan.

Molempien potilastietojärjestelmien avulla voitiin mitata tilannetietoisuuden kehittymistä suuronnettomuudessa vertaamalla paperisista potilasluokittelukorteista saatua tietoa kännykän avulla saatuihin potilasluokittelutietoihin hoitoketjun eri vaiheissa. RFID -järjestelmä osoittautui helppokäyttöiseksi ja se paransi merkittävästi suuronnettomuuksien hallintaa ja tilannetietoisuutta.

Koordinoivat yksiköt saivat RFID -järjestelmällä tietoja uhrien kiireellisyysluokista ja sijainnista yli tuntia aikaisemmin kuin perinteisellä menetelmällä. RFID -järjestelmä on helppokäyttöinen, nopea, vakaa ja osoittautui saumattomasti toimivaksi jopa ankarissa kenttäolosuhteissa. RFID -järjestelmä ylitti kaikilta osin perinteisen järjestelmän. Se tehosti merkitsevästi lääkinnällisen pelastustoiminnan organisatorista valmiutta.

Tässä väitöskirjatyössä uuden tietotekniikan on osoitettu tuottavan suurta hyötyä sekä pedagogisesti, että teknisesti sotilaslääketieteelliseen koulutukseen ja lääkinnälliseen valmiuteen suuronnettomuustilanteissa.

# CONTENTS

# ABBREVIATIONS

| | |
|---|---|
| AIB | Accident Investigation Board |
| BLS | Basic life support |
| BAS | Battalion aid station |
| BVM | Bag-valve-mask |
| CAS | Company aid station |
| CMO | Chief medical officer |
| CI | Confidence intervals |
| cLMA | Classic laryngeal mask airway |
| COTS | Commercial off-the-shelf |
| CPR | Cardiopulmonary resuscitation |
| CRT | Capillary refill time |
| EBMG | Evidence based medicine guidelines |
| ED | Emergency department |
| EMS | Emergency medical services |
| ERC | European Resuscitation Council |
| ETI | Endotracheal intubation |
| EVACH | Evacuation hospital |
| FDF | Finnish Defence Forces |
| FMS | Field medical services |
| FRC | Finnish Red Cross |
| GCS | Glasgow coma scale |
| GSM | Global System Mobile |
| ICD-10 | International diagnosis code guide, version 10 |
| ILMA | Intubation laryngeal mask |
| IAMSR | Institute for advanced management systems research |
| LCC | Low-cost components |
| LMA | Laryngeal mask airways |
| LT | Laryngeal Tube |
| MI | Ministry of the Interior |
| MO | Medical officer |
| MOC | Medical Officer Course |
| MS | Message Systems |
| NBC | Nuclear, biological, and chemical |

| | |
|---|---|
| NBI | National Bureau of Investigation |
| NCO | Non-commission officer |
| NFC | Near field communication |
| PDA | Personal digital assistant |
| RFID | Radio frequency Identification |
| SMS | Short Message Service |
| SM | Service manager |
| TETRA | Terrestrial Trunked Radio |
| VAS | Visual analogue scales |
| VIRVE | Viranomaisradioverkko (Official Radio Network) |

# LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications referred to in the text by the Roman numerals I–IV:

I. Jokela J, Nurmi J, Genzwuerker HV, Castrén M. Laryngeal Tube and Intubating Laryngeal Mask Insertion in a Mannequin by First-Responder Trainees after a Short Video-Clip Demonstration. Prehospital Disast Med 2009; 24(1):63–66.

II. Jokela J, Han S, Harkke V, Kallio M, Lindgren L, Castrèn M. A comparison study of using a mobile medical information system. Journal of Systems and Information Technology 2009; 11(3): 286–294.

III. Jokela J, Simons T, Kuronen P, Tammela J, Jalasvirta P, Nurmi J, Harkke V, Castrèn M. Implementing RFID technology in a novel triage system during a simulated mass casualty situation. Int. J. Electronic Healthcare 2008; (4)1:105–118.

IV. Jokela J, Rådestad M, Gryth D, Nilsson H, Ruter A, Svensson L, Harkke V, Luoto M, Castrén M. Increased situation awareness in major incidents – Radio frequency identification (RFID) technique: a promising tool. Submitted.

# INTRODUCTION

Finland represents a country where the highest level of Information technology (IT) is in daily use. Thus the use of novel IT covers all areas of society, including medical education. Information technology is transforming our daily lives, hence, there obviously exists a need for scientific research on these technologies. The use of novel technologies in healthcare services is also on the increase. Physicians and other medical personnel, including the Finnish Defence Force need to be trained in these technology skills. This need includes technologies for emergency care services, hardware and equipment and the use of a government network, like VIRVE.

Worldwide disasters occur almost daily (Waeckerle 2000). Disasters have claimed nearly three million lives and adversely affected 800 million more in the past 20 years (Schultz et al. 1996). The risk for mass casualty situations is increasing as a result of population growth and industrialisation. Moreover, while recent terrorist incidents have garnered media attention, civilian events with fewer victims can still temporarily overwhelm a community's resources and are, in fact, the more frequent local "disasters" that occur in developed countries (Chan et al. 2004).

In Finland there have occurred several mass casualty situations during the years 1976–2008 (Table 1.).

**Table 1.** Mass casualty situations in Finland, 1976–2008. (Kekki 1976, Lukkarinen 2008, AIB 1997, MI 2003, Pekkarinen 2002, AIB 2004, AIB 2005, NBI 2007).

| Year | Mass casualty situation | Place | Number of deaths | Number of injured |
|---|---|---|---|---|
| 1976 | Lapua cartridge factory explosion | Lapua | 40 | 60 |
| 1978 | Rissala airplane accident | Kuopio | 15 | |
| 1994 | Ferry Estonia sinking in | The Baltic Sea | 852 | 137 |
| 2002 | Bomb explosion in a shopping centre | Vantaa | 7 | 164 |
| 2004 | Traffic accident | Äänekoski | 23 | 14 |
| 2005 | Helicopter accident | Gulf of Finland | 14 | |
| 2007 | The Jokela school massacre | Tuusula | 9 | 12 |
| 2008 | The Kauhajoki school massacre | Kauhajoki | 11 | 3 |

In the case of the Estonia Ferry disaster, the number of injured consisted of passengers rescued from the stormy sea. In the cases of the Rissala airplane and the Gulf of Finland helicopter accidents all those involved perished.

Novel information technology is essential for many reasons in military medicine and mass casualty situations. One of these reasons is that the FDF support other authorities in national events or mass casualty situations. This readiness was manifested in the Kauhajoki school massacre, when the FDF were able to provide executive assistance proactively, flexibly and quickly. The ability of the police authorities in requesting executive assistance has also improved. All in all, the FDF carried out approximately 500 executive assistance tasks in 2008, an average of one and a half per each day of the year (www.mil.fi).

Secondly, FDF participates in international missions for crisis management where high-quality equipment is needed.

As stated in the MI 2003 report of a home-made bomb explosion in a shopping centre in Vantaa, year 2002, the biggest development challenges in mass casualty situations are related to the major problem of the message systems (MS) and their lack of communication systems support to management activities (MI 2003). According to the AIB report of the worst road traffic accident in Finland that occurred at Konginkangas of Äänekoski "in Emergency response, Center described reports occurring at least three different times for the same event. Those times were separated from each other by several minutes difference' in these times. The patient's rights may be weakened by these inaccurate time-markings" (AIB 2004).

The need for improving military medical training given by the FDF was studied in the 1990`s (Jokela 1997). According to Jokela the results reflect the need for a longer period of first aid training in order to achieve the results required in practice. Medics' initial course is four weeks long, including approximately 50 hours devoted to first aid training. A standard war surgery text states: "Skilled medical attendants are needed to maintain the airway, support respiration, control hemorrhage, and ensure the adequacy of blood or fluid volume replacement and perform rapid evacuation" (Bowen and Bellamy 1988, Bowen 2004). Bellamy recommends better training of medics in the recognition of life-threatening wounds (Bellamy 1987). Unfortunately, even in a developed country, the typical Army medic is incompletely trained and inadequately experienced in these tasks (De Lorenzo 2005). The need for revisited medical training has recently been introduced in Finland (Mäkitie 2008).

The aim of this thesis is to increase our knowledge of novel information technology in education in military medicine and mass casualty situations.

This is an area which has not widely been studied. Military medicine and mass casualty situations were chosen as subjects of the thesis because FDF training and cooperation with other security authorities is increasing. In ordinary executive assistance, the FDF typically provide the police and the rescue authorities with equipment, staff and transport capacity as well as expertise with professional staff equipped for the task (Kuronen 2009).

# LITERATURE REVIEW

In a mass casualty situation, the resources that first responders have in both civilian and military settings are limited. When resources become limited, the continued effectiveness of the response depends on skilled supply-and-demand management. The term `situational awareness` is often used to denote a key factor in making timely and effective decisions during rapidly evolving events (Fry and Lenert 2005). Novel information technology and digital-based training are used to better meet the needs of today's students, soldiers and civilian medical personnel. Military medical services will need to pay special attention to this possibility, because of the heavy continuing education requirements imposed on their health care personnel (De Lorenzo 2005).

# 1. APPLICATIONS OF NOVEL INFORMATION TECHNOLOGIES IN MILITARY MEDICINE AND MASS CASUALTY TRAINING

## 1.1 MOBILE INFORMATION SYSTEMS

Healthcare is a very important sector of our society. This sector has rapidly adopted state-of-the art technologies in the clinical and research fields. However, the area of the automated information management has been brought into practice very slowly in comparison with most other major sectors of the post-industrial society (Wickramasinghe and Mills 2001). The healthcare systems in industrialised countries face huge challenges from the changing demographic structure of the population and rising healthcare costs (OECD 2004), and therefore the efficiency of healthcare systems and organisations must be improved. One possible way to achieve this is to change the work processes in healthcare and to take full advantage of existing technologies that could markedly decrease the costs of information management in healthcare. The development of wireless electronic communications along with diminution of electronic devices has led to development of electronic information systems that can be accessed from a variety of portable terminals. The terms mobile, wireless, portable and even ubiquitous have all been used to describe these types of devices and systems (Basole 2004).

The work processes of individual physicians could probably be arranged more efficiently, along with the whole organisation of healthcare so that it is continuously seeking new ways to provide the services needed by an aging population. New knowledge, on how mobile information systems in healthcare settings are actually used and which factors are important for the design of new systems can be given to the IS community and the healthcare organisations. Particularly exploring the possibilities of mobile information systems and knowledge mobilisation in general, and by evaluating a pilot system and its impacts on the work of physicians (Harkke 2006).

## 1.2 MOBILE TECHNOLOGY IN MEDICAL PRACTICE

The advances in information technology have profoundly changed the way things are done in our society as a whole and also within the healthcare sector. Computer assisted technologies have been in use for years in clinical systems. A partial explanation for this is the mobile nature of medical work. At least part of the work is done in surroundings where access to traditional computer terminals is limited. This shortcoming was earlier helped by developing computer trolleys for hospital use (Martins and Jones 2005). The emergence of mobile telephones, Personal Digital Assistants and smart phones has changed this. The technologies in use today enable access to practically all kinds of information through small, portable devices (Ammenwerth et al. 2000). The mobile tools have found large numbers of uses and users in clinical practice (Harkke 2006) and education (Ward et al. 2001). The mobile technologies have, naturally, proven to be most suitable for field work applications in different contexts. Additionally, there are possible advantages for using mobile systems even within the normal working environments (Harkke 2006).

The use of mobile tools in healthcare settings is widely recognised. The mobile or handheld devices have proven their usefulness in the following situations (Harkke 2006):

- Data entry at the point of care (Ault 1998), removing the problems associated with handwriting and separate data entry and enhancing the timeliness, accuracy, richness and confidentiality of the patient data (Lanway and Graham 2003, Carroll et al. 2002). The early documentation systems were, however, reported to take more time to use than the paper-based systems (Shiffman et al. 1999).
- In medication decisions in the form of reference guides (Rotschild et al. 2002) or linked systems with some decision support capabilities (Nightingale et al. 2000, Grasso and Genest 2001). These systems have stopped potential medication errors and streamlined the routines by enabling medication decisions by the bedside.
- In specialist care situations with decision making, and in telemonitoring and remote diagnosing by specialists in locations other than the patients (Shiffman et al. 2000, Reponen et al. 2000).
- In an emergency care setting in the form of a cart containing a wireless networked computer (Bullard et al. 2004).

- In ambulatory settings in emergency care in the form of easily accessible guides and drug references (Shah 2003), decision support systems (Karlsten and Sjöqvist 2000) and telemonitoring systems (Pavlopoulos et al.1998). In critical care surroundings in the form of reference guides, drug calculators and connection to patient records (Lapinsky et al. 2001).
- Bringing the possibility of using evidence-based medicine (the conscientious, explicit and judicious use of current best medical evidence (from systematic research) in making clinical decisions about the care of individual patients (Sackett et al. 1996) to the point of care (Vogel et al. 2003).
- Providing the patients with useful information and educational material (Magos et al. 2004).
- In coding and managing billing and insurance claims (Morrison 2002).
- In providing contacts to library resources and online information (Shipman and Morton 2001).
- In a number of general and versatile uses (Chasin 2001, Chin 2001, Connor 2001, Ebell and Rovner 2000, Fischer et al. 2003, Blackman et al. 1999, Volsko 2004, Martyn 2003, Tapellini 2000, Stammer 2001).

## 1.3 USE OF A RFID TECHNOLOGY IN THE PATIENT INFORMATION WORKFLOW IN MILITARY MEDICINE AND MASS CASUALTY SITUATIONS TRAINING

Disaster response to mass -casualty incidents represents one of the greatest challenges to a community's emergency response system. Rescuers, field medical personnel and regional emergency departments and hospitals must often provide care to large numbers of casualty victims in a setting of limited resources, inadequate communication, disinformation, damaged infrastructure and at great personal risk. Emergency care providers and incident managers attempt to procure and coordinate resources and personnel, often with inaccurate data regarding the true nature of the incident, needs, and ongoing response. In this chaotic environment, new technologies in communications, the Internet, computer miniaturisation, and advanced "smart devices" have the potential to vastly improve the emergency medical response to such mass-casualty incident disasters (Chan et al. 2004). Fry and Lenert (2005) theorise that real-time location of medical 'assets' using RFID tags and a visual dashboard would be similarly useful in responding to disasters with numerous injured patients. These systems allow real-time patient tracking as well as mobile data acquisition in the field, ambulance, and hospital to create a portable medical record. The use of radio frequency identification has recently been used to track patients and their location when receiving emergency care. RFID technology is also being used to track equipment and other resources (Chan et al. 2004).

RFID tags, (also called transponders), can be categorised into two groups: active or passive. An active tag is powered by a battery inside the tag that assists in the transmission of the data on the chip to a reader which may be up to 100 feet away. A passive tag is actually powered by the RFID reader. When the tag comes within range of the reader, the reader's interrogation "wakes up" the tag, giving it enough power to transmit a response (Xiao 2008).

Unlike the other industries that handle goods, healthcare services face unique challenges in that they deal with people. Most of the manufacturing or retailing businesses use passive RFID technology while the healthcare industry uses the more expensive active RFID tags to keep track of patients, staff and expensive equipment. The healthcare community is always investing in new technology to improve patient care service, reduce human errors and increase service efficiency. Since RFID technology has been successfully implemented by manufacturing, transportation, retail and other industries to track and verify items, the healthcare community in recent years has been seriously considering its use to enhance patient safety and improve business processes. The IDTechEx published a report entitled "RFID for Healthcare and Pharmaceuticals 2009–2019" in July 2009 (Harrop and Das 2009). According to the statistics of 2000 cases of RFID in action, the distribution of RFID applications in healthcare is shown in Table 2.

**Table 2.** RFID application distribution in healthcare (Harrop and Das 2009).

| Application | Number of case studies as a percentage of all RFID applications | Comment |
|---|---|---|
| People tagging | 26% | Mainly patients for error prevention followed by staff for location/ alarm |
| Assets | 16% | Mainly fixed assets and valuable consumables for preventing theft and misplacement, and for rapid location |
| Pharmaceuticals | 13% | Trials and one rollout in 2005 for anti-counterfeiting, and one large application and many trials for error prevention |
| Blood | 4% | Error prevention mainly |
| Other | 41% | Cards, key fobs, pendants and badges for secure access, health records and payment. Supply chain management e.g. pallets, cases and vehicles |

The benefits of RFID technology in the healthcare sector can be summarised as follows:

Medical equipment tracking and management (Britton 2007)

- Reduced time to find assets (Davis 2004)
- Increased utilisation (Østbye et al. 2003)
- Reduced loss (Rangarajan and Vijaykumar 2005)

Patient identification and tracking (Bacheldor 2007)

- Reduced human errors (Chao et al. 2007)
- Improved patient care service (Chao et al. 2007)
- Read data without requiring direct line of sight (Venkatesan and Grauer 2004)

Blood product management (Jervis 2005)

- Increased safety (Sandler et al. 2006)
- Speed of response to critical events (Al Nahas and Deogun 2007)

Pharmaceutical applications (Angeles 2005)

- Counterfeit drugs (Staake et al. 2005)
- Ensured patient safety (Wu et al. 2005)
- Improved inventory management (Barua et al. 2006)
- Faster product recalls (Attaran 2007).

Xiao has recently showed the potential of using RFID technology in mass casualty incidents (Xiao 2008). Instead of manually updating files, a victim's injury records can be stored in an RFID wristband that accompanies him or her throughout triage and may be updated during transportation. The tag allows nurses and doctors to spend more of their precious time on patient care instead of on paperwork. Not only will the proposed method increase the efficiency of mass casualty workflow, but it will also provide more accurate records by reducing errors. Moreover, it makes it possible for nurses and doctors to view any patient's complete record whenever they are close to the patient.

## 1.4 USE OF VIDEO IN TRAINING FOR THE LARYNGEAL TUBE AND THE INTUBATING LARYNGEAL MASK AIRWAY

Computer multimedia has the potential to provide learners with training experiences that traditional text-based methods cannot (e.g., interactive patient consultations) (Mooney and Blight 1997). In their study of videotape use in clinical education, Mir et al. (1984) found that videotaped demonstrations are as effective as personal ones. In teaching medicine, the videotape method has proven to be effective and reliable (Hogan and Boone 2008, Pasquinelli and Greenberg 2008). Now videotapes have been replaced by computer video files.

Interestingly, there are several Internet programmes that may be able to introduce new surgical procedures to surgeons. Video tutorials within simulation training have proven to be efficient and cost-effective in surgical training (Stefanidis et al. 2007).

Establishing and securing an open airway plays an integral part in basic life support. The cuffed endotracheal tube remains the gold standard for restoring and maintaining adequate blood oxygenation to patients in respiratory distress. However, endotracheal intubation can only be used by experienced personnel (Nolan et al. 2005).

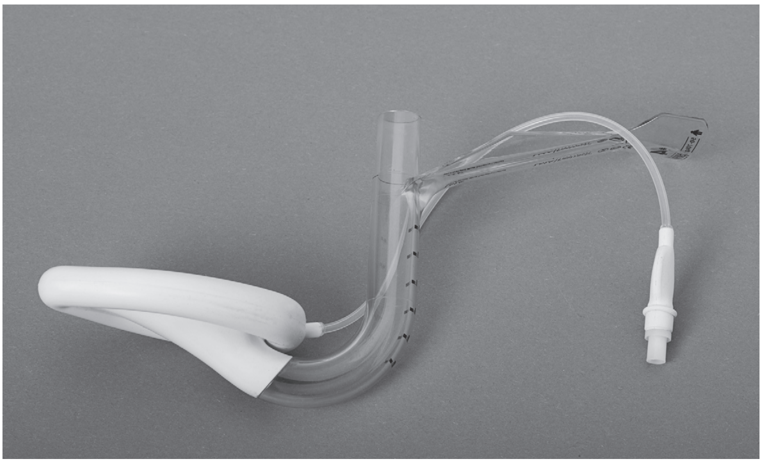
Ventilation using a facemask is another option, but has several potential risks, including over-ventilation with gastric inflation and subsequent regurgitation, which must be taken into consideration (Stone et al. 1998). To overcome the difficulties and risk factors associated with intubation and face masks, the laryngeal tube (LT) (Agro et al. 1999, Genzwuerker et al. 2000, Dörges et al. 2000) and the intubating laryngeal mask airway (ILMA) (Brain et al. 1997) have been developed. These devices are inserted blindly into the patient's oropharynx.

The LT, a single-lumen device, was introduced in 1999 (Dörges et al. 2000, Genzwuerker et al. 2000, Agro et al. 1999). An identical, polyvinylchloride (PVC) version of the LT for single use has been available since 2004 (Genzwuerker et al. 2005). It has two cuffs that are inflated with a single syringe. The distal cuff lies at the orifice of the oesophagus and the proximal cuff blocks the pharynx at the base of the tongue between the two cuffs, where two apertures through which air enters the lungs via the larynx.

The original laryngeal mask airway (LMA), also known as the classic LMA (invented in 1981), was modified in 1988 by adding an inflatable cuff and using latex and silicon. It gained vast success in UK hospitals in 1989 and was approved by the US Food and Drug Administration in 1991 (Brain et al. 1991). The classic LMA is recommended by the European Resuscitation Council (ERC) (Nolan et al. 2005). The ILMA (LMA-FastrachTM), a variant of the LMA, was introduced in 1999 (Dörges et al. 2000, Genzwuerker et al.2000, Agro et al. 1999). Compared to the standard LMA, it is inserted without digital manipulation and is designed to be used with the patient's head and neck in the neutral position or with cervical spine immobilisation. The ILMA also allows blind or fiber-optically conducted tracheal intubation without removal of the device (Komatsu et al. 2005).

Asai et al. (2002) tested the efficacy and performance of LT by 28 inexperienced fireman students in a randomised cross-over study comparing LT and LMA in a mannequin. Insertion was found to be easy in both groups. Kurola et al. (2004) compared the initiation and success of ventilation with the LT, ETI and bag-valve mask (BVM) in a cardiac arrest scenario. Sixty emergency medical technician (EMT) students formed teams of two rescuers at random and were allocated to use these devices. The LT and ETI provided equal minute volumes of ventilation, which was significantly higher than that delivered with the BVM. Their data suggest that the LT may enable airway control as effectively as ETI, but more rapidly and compared to BVM, may provide better minute ventilation when used by inexperienced personnel. Genzwuerker et al. (2005) evaluated the potential role of the laryngeal tube as an alternative to face mask ventilation and a means of airway maintenance by inexperienced users. They didn't find differences between the two devices.

**Picture 1.** Disposable laryngeal tube (LT)



**Picture 2.** Intubating laryngeal mask airway (ILMA).

## 1.5 AIRWAY TRAINING MANNEQUINS AS A SIMULATOR FOR INSERTING THE LARYNGEAL TUBE (LT) AND INTUBATING LARYNGEAL MASK AIRWAY (ILMA)

Clinical research and international guidelines support the use of the laryngeal tube (LT) and the laryngeal mask airway (LMA) for resuscitation at the time of cardiac arrest (Nolan et al. 2005). There is therefore increasing interest in the use of mannequins for teaching airway skills to first responders and lay people. While insertion of the laryngeal tube and laryngeal mask airway is not an intrinsically difficult procedure, a mannequin that closely reproduces the performance in humans would be beneficial for training. A mannequin that allowed 'off-patient' evaluation of these devices would also be useful. Traditional mannequins are designed primarily for simulation of tracheal intubation and ventilation by facemask (Silsby et al. 2006).

Genzwuerker et al. (2005) and Kurola et al. (2004) used an AMBU® Mega Code Trainer (Ambu Corp., Copenhagen, Denmark) for training and recording of data. The mannequin allows measurement of tidal volumes and recognition of gastric inflation, when the peak inspiratory pressure exceeds 15 cm H2O (Genzwuerker et al. 2005).

## 1.6 A MOBILE MEDICAL INFORMATION SYSTEM

A mobile medical information system was developed by the Finnish Medical Society, (www.terveysportti.fi/dtk/ltk/koti). It is a set of medical information and knowledge databases which support the physicians' medical practice by retrieving knowledge and information when needed (www.hightechfinland.com 2004). It contains the Evidence Based Medicine Guidelines (EBMG) with Cochrane abstracts, the pharmacology dataset Pharmaca Fennica with wireless update service for a complete medicine price list in Finland, the International Statistical Classification of Diseases and Related Health Problems (ICD-10) in Finnish, the Emergency Guide Issued by Meilahti hospital, a medical dictionary of over 57,000 terms and a comprehensive database of related addresses and contact information relevant to healthcare (pharmacies, hospitals, healtcare facilities) (www.terveysportti.fi/terveysportti/tunnistus.ebmgsivu). The system also includes a drug interaction database originally developed by the Karolinska Institute, Sweden. The system is built on an XML database and can easily be modified to work with most mobile devices, using different operating systems such as Symbian, Palm OS, and Windows CE. In Finland, the devices most commonly used as mobile information platforms are the Nokia Communicator 9210, 9310 or 9500. Currently, updates are delivered on memory cards.

However, in the near future the system will be able to update itself partly, or completely, through the wireless network. The system is designed for and used by civilians (Han 2005, Harkke 2006).


**Picture 3.** The Mobile Medical Information System.

## 1.7 MASS CASUALTY SITUATION AND TRIAGE

The numbers of natural and man-made disasters around the world continue to rise (WHO 2005). Mass casualty situation is defined as any large number of casualties produced in a relatively short period of time, usually as the result of a single incident such as an aircraft accident, hurricane, flood, earthquake, or armed attack that exceeds local logistic support capabilities (www.thefreedictionary.com). The challenge is to ensure accurate and timely sharing of information in the fastest manner between the various parties and systems when the hospital handles the influx of patients from the mass casualty situation. Emergency service, hospital, local and regional disaster plans are being revised to respond to these new and increasingly likely events. However, it is probable that many plans have been verified without testing how they work in a casualty surge. The two fundamental aims of a disaster response are rapid evacuation of all casualties from a hazardous incident scene, and reduction in the mortality of critically injured patients (Hirshberg et al. 2001). Rapid evacuation of all casualties is vital where there is the potential for structural collapse or secondary explosive devices. However, reducing critical injury mortality requires careful assessment to identify these severely injured patients among the large numbers of non-critical casualties. Scene clearance should therefore be highly organised and efficient to optimize casualty triage and survival. Rapid scene clearance creates a surge in the rate that casualties arrive at receiving institutions. A fundamental issue in mass casualty care is not simply the number of patients that need treatment, but also the rate at which they arrive and use available resources. The ability to maintain standards of trauma care is reduced by this casualty surge and the ability to provide high-level trauma care under these circumstances is termed 'surge capacity' (Aylwin et al. 2005).

The term triage derivates from the French word "triage" meaning a process or a system of assessing how seriously ill or injured people are and treating the most serious cases first. In practice triage is a process used by medical personnel, defined as the sorting and classification of casualties according to the need and urgency for acute medical care, which can take place anywhere along the line of evacuation, from the point of injury to the hospital, where definitive treatment is given (Dufour et al. 1988). Triage has been called the keystone of the management of mass casualty situations and has shown to be the most important determinant in combat casualty care (Auf Der Heide 1989, Iserson and Moskop 2007, Swan and Swan Jr 1996). The North Atlantic Treaty Organisation (NATO) forces, as well as many civilian systems, classify casualties into four categories based on the need and urgency for medical care:

1 immediate (cannot wait)
2 delayed (has to wait)
3 minimal (can wait)
4 expectant (dead or dying) (Bowen and Bellamy 1988, Bowen 2004. (Figure 1.)

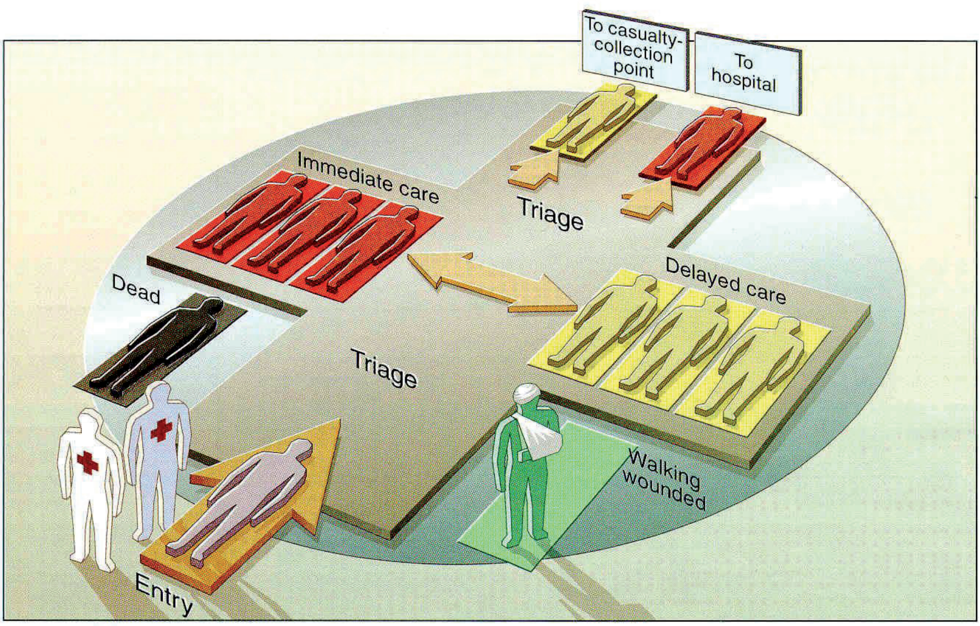



Figure 1. Triage has classified casualties into four categories.

The classification of the casualties according to their need for medical care and to ration the limited medical resources aims at doing the greatest good for the greatest number of casualties. Triage classification is frequently a complex task requiring the precise yet rapid assessment of the patient, as well as sufficient medical knowledge of potential pathophysiology. Triage in the field also requires the quick and distinctive marking of the casualties according to their triage category. The prioritisation of the casualties according to their categories ordains their order for both treatment and evacuation (Cross 2006, Greaves et al. 2001, San Pedro et al. 2004 and 2005).

Though technological aspects are of great importance in training, tactical skills needed in field conditions should not be underestimated, i.e. field medicine. Skills of these kinds are, in addition to novel information technology, an essential part to success in emergency and military medicine (Schwarts et al. 2008, Mäkitie and Hänninen 2007, De Lorenzo and Porter 1999).

Around the world the paper tags are utilised to identify and track injured individuals when responding to mass-casualty situations (Lenert et al. 2005). Prioritization of casualties is therefore an important part of all training in patient management at disasters and major incidents, as well as the use of different symbols in different colours that indicate the priority of the victim. The general accepted meaning of the colours is that red indicates a seriously wounded, 'immediate; casualty; yellow indicates urgent or delayed; and green, minor injuries or "walking wounded". In some systems there is also a blue colour that indicates expectant. These coloured tags, priority tags, can have different design and can also contain other information and at the same time be used for documentation purposes. Although priority tags are considered important in all training and education, there are few, if any, reports on their actual use in real incidents. Nor has there been much research on how medical personnel consider when the tags should be used (Nilsson and Rüter 2007).

A priority tag should be waterproof and writing on a tag should be possible even if the triage tag is wet or in a cold environment. It should be easy to attach securely to the victim, small but easy to see from a distance and the coloured priority category should be easy to change, (if the condition of the patient changes). The training to use triage system should be simple and take a short time, (only a couple of hours). The proper use of priority tags requires periodically arranged training for all medical personnel which are involved in the emergency care of the mass casualty situation. Priority tags contain information about the victim: the priority level for medical evacuation, gender, age, name, and vital signs as the respiratory rate, pulse rate, Capillary Refill Time (CRT), the level of consciousness, Glasgow Coma Scale (GCS), blood pressure and treatment given to the victim. In military operations the priority tag can be personal: each soldier can have a tag with his/her identity information, sometimes with the blood type, medical history, allergies and possible medications. It is often placed into soldiers personal Improvised First-Aid Kit (IFAK). If the soldier gets wounded, the team medic can use the personal tag with soldiers ID. In some triage systems priority tags are used alongside the coloured tapes. The paper priority tags are in that case giving all the other information about the victim, but the colour tape indicates the priority class of the victim. The colour triage classification tape is normally attached to the wrist of the victim. The colour tape is changed if the triage classification of the victim changes.

One example of a developed triage tag system is the Smart Incident Command System. It has been developed by a private British company and it is the most common triage system worldwide. It's advanced but simple ideas are based on the long time work and cooperation with the EMS and military medical sector. It is used by British military and many other NATO countries in Europe, as well as Swedish and Irish Defence Forces. Additionally by Finland's Nordic Battle Group as well as by civilian emergency medical services and hospitals in United Kingdom, Ireland, Iceland, Sweden, the Netherlands and United States of America. Smart Incident Command System consists of a memory card for making the primary triage, the chemical and waterproof triage tags, nuclear, biological, and chemical (NBC) tags for victim's contaminated by nuclear, chemical or biological agents, chemical light sticks to show victims priority class visible in the darkness, small carry packs and incident command and hospital control boards. The system also contains training material, which makes medical personnel training easy and possible to carry out in a classroom or in a natural environment. If the victim is unidentified, priority tags have a number code for each triage tag. One side of the tag can be taken off. It has the victims ID code and a place to write the name and other ID information. When the victim is prepared for the medical evacuation, this side is left for the logistic/transportation leader. Smart Triage Tag Priority categories 1–3 (P1 Red, P2 Yellow, and P3 Green) are on the sides of the Tag. The chosen Triage Priority code is clear if flipped on the visible side. If the P1-P3 category changes the code and colour on the top can be changed in seconds. The Triage Tag is attached inside a see-trough plastic pocket and then attached with a rubber band to the wrist or neck of the casualty/victim. Priority category 4, coloured as Black is indicates the victim is DEAD. In the Smart Triage system only medical personnel carry black DEAD tags. Individual soldiers do not have them for psychological reasons. A casualty would get extremely anxious while seeing one's personal triage category as dead. In triage, the primary survey is done by sorting out the victims to those who are able to walk and are not injured, and to injured victims who are walking or are not able to walk. Walking but injured victims classed as Priority 3 (Green). Next with non-walking victims the breathing and the airway are checked: is the airway open? Is he/she breathing after simple and fast airway opening procedures? If not, the victim is dead. If the patient is breathing, the respiratory rate is quickly evaluated. A respiratory rate below 10/min or over 30/min places the victim into the Priority 1 (Red). A pulse rate of 120 /min or more places the victim into the Priority 1 (Red). Pulse rates of less than 120 /min with a respiratory rate between 10–29 /min places the victim to the Priority 2 (Yellow). Non-injured, walking victims are sent to the casualty reception area. Priority 1 (Red) are patients with life, limb or sight-threatening injuries (for example, catastrophic haemorrhage, airway obstruction or tension pneumothorax). Treatment is essential within an hour. Priorities 2 (yellow) are patients with serious injuries that require treatment within 2 hours (for example, fractured shaft of femur however, this could be categorised as priority 1 if the fracture was open and the haemorrhage was substantial).

## 1.8 SITUATIONAL AWARENESS

Traditionally, medical command makes decisions using a paper-and-radio system. Triage, treatment, and transport officers fill out tallies and create written reports while also performing their primary duties. These reports are periodically hand-carried or called into the medical command, where they are manually reviewed, summarised, and posted. This labor intensive process creates variable latencies, and incomplete and low-resolution data (Demchak et al. 2007).

The term 'situational awareness' means the comprehension of situation-specific factors that affect performance in complex tasks and it renders possible the making of real-time effective decisions during rapidly evolving events. When situational awareness is lost, supervisors make resource allocation decisions blindly, staff and equipment are utilised sub-optimally and patient care is negatively impacted. It is of great importance, particularly in the medical response to major incidents, in which the effective use of limited resources has direct implications on the care and survival of the casualties. Tools and techniques that monitor and communicate the state of business processes are essential to preserving situational awareness. More sophisticated facilities may track patients using bands with barcode ID or monitor bed occupancy as secondary indicators of the demands being placed on the healthcare delivery system (Fry and Lenert 2005).

The successful use and implementation of continuously evolving mobile and wireless technologies in several fields have also highlighted the opportunities of applying them in the field of healthcare and their potential importance for supporting timely access to decision-critical information (Padmanabhan et al. 2006). In addition SA is explicitly recognised as a being separate from decision making and performance. Even the best-trained decision makers will make the wrong decisions if they have inaccurate or incomplete SA. Conversely, a person who has perfect SA may still make the wrong decision (from a lack of training on proper procedures, poor tactics, etc.) or show poor performance (from an inability to carry out the necessary actions) (Endsley 1995).

# 2. MEDICAL TRAINING IN THE FINNISH DEFENCE FORCES (FDF)

## 2.1 THE AIM IS WARTIME FORCE

Military training in the FDF provides training and orientation for conscripts in competencies skills beneficial for national defence and thus can provide the necessary prerequisites for the country to form complete units in the event of war. This means that each conscript must be trained for wartime duties according to his or her abilities and skills. Military service is compulsory for all males and voluntary for females in the country. Conscript training takes place in the Army, Navy and Air Force or Border Guard.

## 2.2 BASIC TRAINING PERIOD

The beginning of military service, with regard to the content of training and the basic training period is the same for all conscripts. Each conscript receives the basic training of a soldier and takes the basic military examination. The basic training period is similar in character throughout all the services and arms of each service. During the basic training period, selections are made and conscripts are designated to leadership training and specialist training branches. After the basic training period, conscript training is differentiated and some conscripts are trained for leadership roles. Most of the conscripts are prepared to be combatants or trained for other specialist roles, for example medics (www.mil.fi).

## 2.3 UNIT TRAINING PERIOD

Training of the wartime force takes place at the end of the service period for rank and file (180 days), which is called the unit training period. The unit training period lasts 24 weeks. The aim is that the training and other activities take place in as realistic circumstances as possible, comparable to a wartime situation including training in refresher exercises after the service period. The unit training period is the peak of the entire conscript training period with regard to skills and knowledge. Voluntary military training also improves the performance capability of the wartime troops of the Defence Forces. It is given in the training, such as military courses and exercises commissioned from the National Defence Training Association (www.mpkry.fi).

## 2.4 COMBAT MEDIC TRAINING

The standard of training and performance of medical personnel in modern, developed armies is high. Detailed medical skills, requirements that every medic should know are described in many handbooks, both international and domestic (Bond 2009, PHTLS 2005, Koskenvuo 1994, Koskenvuo 1995).

Medics are trained by military personnel who are responsible for providing first aid and frontline trauma care on the battlefield. Medics are also responsible for providing continuing medical care in the absence of a readily available physician, including care of diseases and battlefield injuries. Medics are normally located within the units they serve, in order to easily move with the troops and monitor ongoing health. Medics are conscripts specialised in the field of medical care, with a service period of 270 days. They are trained in combat medic courses during the specialist training period after basic training, in various branches of the military. The entrance requirement is usually service class A with a normal level of fitness and stress endurance. Preferred for selection are those who have worked in the healthcare sector, the emergency services or are interested in the medical field. The length of the theoretical part of the medic course is four weeks. Medics then continue their training with a mix of a peacetime healthcare period in their units, for example in their wartime tasks and others such as live-fire exercises and battle drills. Finally, training should take into account their unit's own specialisation and service branch (Army, Air Force or Navy). There are in existence different national solutions between developed countries, but the main tasks of the training programmes for medics are quite similar.

The final tasks nowadays are that medics are trained medical specialists who provide emergency care to personnel while in field. Moreover, they are responsible for care and treatment of injuries whether at the aid stations or on the battlefield.

## 2.5 MEDICAL NON-COMMISSIONED OFFICERS (NCO) TRAINING

Medical non-commissioned officers (NCOs) are trained in the Centre for Military Medicine in a nine week theoreticallybased medical phase of an NCO course. Before this, medical NCO students go through their unit's own NCO course (Phase I, seven weeks). These medical NCO students are chosen according to their unit's own requirements. Priority is given to those in the healthcare and emergency services; nurses, paramedics, fire fighters and emergency personnel, as well as those interested in medical NCO tasks. Eligibility criteria are the same as for those of the combat medic. After the course, medical NCOs continue training in both their own peacetime and wartime duties. The objective of training is to produce a medical NCO capable of managing a medical team. Also the NCOs must master their own specialisation within their unit, alongside their own leadership role. The aims of medical NCO courses are listed in Table 3 (www.mil.fi).

In the Finnish Defense Forces (FDF), the total compulsory period for conscripts that become medical NCOs is 362 days. The first eight weeks consists of basic training. After basic training and phase 1 of NCO course, they participate in theoretically based period of practical training in first aid and basic life support in the FDF Medical School. After graduating from the Medical School, the NCOs return to their own units where they practice and improve their skills in first aid and basic life support by working at the FDF's health services. By working at the health centre of garrison they also participate in martial training in the field and camps, where mannequin are, as a rule, employed in simulated situations.

**Table 3.** Main aims of the medic, medical non-commissioned officer and medical officer course.

| The aims of the medic course | The aims of the medical non-commission officer course | The aims of the medical officer course |
|---|---|---|
| 1. Can provide life-saving first aid to an immediate life-threatening combat injury<br>2. Can evacuate casualties from the battlefield<br>3. Has knowledge of NBC medical care<br>4. Has knowledge of common diseases occurring in field conditions<br>5. Has knowledge of the medical services organisation and knows the international laws regarding medical personnel | 1. Manage a medical team<br>2. Provide life-saving first aid and basic primary care in field conditions along with transport positions and monitoring during evacuation<br>3. Has knowledge and can manage a battalion level aid station<br>4. Has knowledge of NBC medical care | 1. Lead and manage company and battalion-level emergency medical care<br>2. Manage typical war trauma, along with NBC medicine, in field conditions<br>3. Manage field hygiene and know the basic principles of food and water hygiene, as well as recognising food poisoning epidemics and their prevention in the field<br>4. Know the international conventions concerning in military medical personnel |

## 2.6 MEDICAL OFFICER TRAINING

Recruits in the Medical Officer Course (MOC), held at the Centre for Military Medicine in Lahti, southern Finland, are physicians, veterinarians, dentists, pharmacists or students of these disciplines with the right to clinical practice. The course is arranged annually. Each course has duration of 14 weeks. The medical training takes the form of classroom training as well as field exercises. The recruits also receive leadership and military training. The training programs are under going thorough revision (Mäkitie 2008). The aims of education and training have similarities to those in NATO countries and the Finnish solution of field medicine corresponds to NATO standard specialty in international crisis management (Lehtomäki et al. 2008).

In practice, the education of medical personnel serving in the FDF as well as the development of field medicine, is centralised to the Centre for Military Medicine. There is also a professor of military medicine in the University of Oulu.

To sum up, medical care in new war time operational units is strong and thus there are urgent needs to have high quality medical training from the point of injury to the evacuation hospital (Laapio 2007).

## 2.7 FIRST AID TRAINING IN THE FDF

First aid is the emergency care given to an injured or acutely ill person at the scene, using readily available resources. The FDF follows the Finnish Red Cross (FRC) programmers. The FDF also instructs in first aid from a military perspective to ensure our soldiers consider operational factors, such as terrain and enemy presence, to effectively helping injured personnel (Table 4) (Mäkitie and Hänninen 2007, International Liaison Committee on Resuscitation 2005, Punainen Risti 2007).

According to the FRC 2009 implementation guide, first aid training is mandatory for every first aid and health educator. The FDF trains some 500 medics and 260 medical NCOs every year. It is worth mentioning that so called "tactical combat casualty care" training for specially chosen combat medics and combatants serving in the special forces of the FDF has also been initiated (Mäkitie 2008). After one finishes military service and reenters civilian life, the essential prerequisites for maintaining as well as improving learned skills are the organising of refresher courses and the possibilities for repetition exercises at regular intervals.

## 2.8 ASPECTS OF SIMULATION IN MILITARY MEDICINE

Simulation specialists should have at least a rudimentary understanding of the needs required to run a simulation in military medicine, since the use of simulation as an aid to military training is not new. For example, battlefield simulation is an accepted form of military training and many areas including aviation and mechanised warfare employ simulator systems to improve the scope and range of training opportunities.

Simulation is a "person, device, or set of conditions, which attempts to present evaluation problems authentically. The student or trainee is required to respond to the problems as he or she would under natural circumstances. Frequently, the trainee receives performance feedback as if he or she were in the real situation" (McGachie 1999).

The use of simulation in military medicine in the FDF has been available since 2001.

Realistic training of health personnel for the resuscitation of military casualties is often challenging. There are few opportunities for personnel to obtain the necessary experience unless working in a busy emergency or trauma environment. Even so, the specific nature of military trauma means that many aspects of casualty management may not be adequately covered in the civilian domain (Henrickse et al 2001).

Educationally, a three-level hierarchy in medical simulation is often used. At the first level, microsimulation aims at honing basic technical skills of individual clinicians. At the second level, mesosimulation aims to train clinicians to work more effectively and efficiently as part of a clinical team. At the third level, macrosimulation aims to assess organisational fitness for purpose at large scale (Arora and Sevdalis 2008).

Simulation training helps in the learning process. Pedagogically, learning can take place at a number of levels. At the most basic level, the learning process requires the acquisition and comprehension of new knowledge and associated skills (declarative knowledge). At a more advanced level, the correct application of such knowledge is developed (procedural knowledge) along with an ability to utilize it to problem solve (experience). The highest level involves the use of experience both successfully and unsuccessfully to provide potential solutions to new problems whilst performing in unfamiliar environments or distracting circumstances (Henrickse et al. 2001).

It is noteworthy that aviation simulation has been readily adapted into field anaesthesia (Howard et al. 1992). The same basic properties of crisis such as uncertainty, risk, rapid change and complexity are as apparent in anaesthesia as they are in aviation. The similarity of crisis exists within military trauma resuscitation and the benefits for simulated practice are quite apparent (Hendrickse et al. 2001).

Experience with significant numbers of military teams being trained through the medical simulation facilities of the FDF has shown that time spent in the simulator is perceived as excellent training (Ora 2006). However, planning is always required to assess what simulation is appropriate for which level of training need. Moreover, a good performance capacity of a soldier in the battlefield, as well of medical personnel, (in addition to their combat and medical skills), is based on team cohesion and the justice of the operation. These aspects should be strongly remembered from a military medical point of view.

**Table 4.** Finnish Red Cross First Aid Courses.

| First Aid Course | Course Contents |
|---|---|
| Basic first aid EA 1, 16 h<br>Gives basic knowledge and skills to help in case of emergency and in the most common accidents and health disorders.<br>EA 1-certificate, valid for three years in all European countries. | • Accidents and their frequency<br>• Action in an emergency<br>• Examining the patient<br>• Performing CPR<br>• Health disorders<br>• Bleeding and shock<br>• Wounds<br>• Head and face injuries<br>• Bone and joint injuries<br>• Poisoning<br>• Burns and scalds |
| Advanced first aid course EA 2, 16 h<br>The knowledge and skills acquired in the basic course are built upon for more advanced preparedness.<br>A valid EA 1-certificate is required for all participants. | • Repeat of emergency first aid<br>• Examining injured patients and mechanism of injury<br>• First aid of various injuries<br>• From first aid to first response<br>• First aid and first response equipment<br>• First aid tactics and implementing<br>• Health and safety<br>• Special first aid |

# AIM OF THE STUDY

The aim of the thesis was to study the application of novel information technologies in Finnish military medicine and in civilian mass casualty situation training.

The specific aims were as follows:

1. To investigate the applicability of the LT and the ILMA as the first airway management device in military medicine after a short video-clip teaching the technique. (I)
2. To investigate what differences there are in behaviour and perceptions of the usage of mobile systems between civilian medical students and physicians undergoing compulsory military service in Finland. (II)
3. To determine the applicability of Radio Frequency Identification (RFID) technology to provide an online triage system for handling mass casualty situations. (III)
4. To investigate the potential and technical reliability of RFID to provide realtime overall situational awareness to those overseeing the rescue operation, especially in the medical management of patients. (IV)

# 3. POPULATION, MATERIAL, AND METHODS

## 3.1 MAIN FEATURES OF THE POPULATION STUDY

Studies presented here were done in co-operation with the Centre for Military Medicine, University of Oulu and the Karolinska Institute in Sweden. The study population consisted of conscripts of the Centre for Military Medicine, medical students at University of Oulu and volunteers at Karolinska Institute. The population, applications and methods used in the studies are shown in Table 5.

**Table 5.** Populations, applications and methods of studies I–IV.

| | Study I | Study II | | Study III | Study IV | |
|---|---|---|---|---|---|---|
| | Non-commissioned officer students | Medical officer students | Medical students | Medics students | Medics | volunteers |
| Female | 4 | 1 | 23 | 2 | - | 10 |
| Male | 56 | 27 | 7 | 10 | - | 7 |
| Total | 60 | 28 | 30 | 12 | 18 | 17 |
| Application: | Short video clip | Mobile medical IS | | mTriage | mTriage | |
| Methods: | VAS 1 and VAS 2 | Questionnaire 2 | | Question-naire VAS 1 and VAS 2 | Questionnaire | |

## 3.2 INVESTIGATIONS USING SHORT VIDEO-CLIPS (STUDY I)

In study I, 60 volunteer NCO students (56 males and 4 females) between 18 and 21 years of age, at the Centre for Military Medicine participated in the study after receiving 50 hours of training in first aid and basic life support. The participants had had no health-related training before this training.

The conscripts were randomly assigned into one of two groups: 30 trained to use the LT and 30 the ILMA group. Prior to the actual study, one participant withdrew from the ILMA group. The subjects in the LT group were shown a 35 second video-clip demonstrating insertion of the LT. The subjects in the ILMA group were shown a 20-second video-clip on the insertion of the ILMA. The setting in the test room was identical for both groups. A Resusci® Anne Simulator (Laerdal Medical AS, Stavanger, Norway) was placed on the floor; its airway was prelubricated with a water-based gel. The same method was used by the Genzwuerker et al. (2005) and Kurola et al. (2004).

The devices in this thesis, the LT and the ILMA, were chosen for their superior simplicity of use by non-trained personnel (Kurola et al. 2004, Cook and Hommers 2006).

The Laerdal Resusci Anne Simulator employed in the present study has previously been used in various mannequin trials (Genzwuerker et al. 2005, Genzwuerker et al. 2003). The use of a mannequin in the primary evaluation and comparison of different devices and instruments for airway management is recommended by the authors. First and foremost, a mannequin is not subject to individual variations that human beings are, and no harm can be done to a mannequin (Silsby et al 2006). Thus, the factors determining the ease or difficulty of insertion and the basis for evaluation of the insertion technique remain identical and unaltered for all test subjects and depend mainly on the instrument to be inserted and the manual skills of the subjects. The use of the mannequin also allowed for the measurement of the tidal volumes and recognition of gastric inflation, when peak inflation pressure exceeded 150 mmHg H2O (Genzwuerker et al. 2003).

## 3.3 INVESTIGATIONS WITH MOBILE MEDICAL INFORMATION SYSTEMS (STUDY II)

In study II, groups of civilians were compared to military personnel. Participants of the civilian group of this study were sixth year medical students. Of the military personnel (MO students), most had just finished their studies, hence the training level of the two groups was very similar. During 2005 and 2006 the test groups answered the questionnaires after using a mobile medical information system for several months. In the comparison we aimed at finding the differences in system usage and requirements between civilian and military (field) conditions.

## 3.4 INVESTIGATIONS OF TRIAGE WITH RFID TECHNOLOGIES IN MASS CASUALTY SITUATIONS (STUDY III-IV)

### *3.4.1 Geography*

The "PYRY06" exercise was the name for a Finnish military exercise in 2006, where study number III was undertaken. Geographically, the area of operations was situated in Central Finland. The first test of study IV took place at Lake Vesijärvi in Lahti, some 100 km to the north of Helsinki. The second test of study IV took place at the international airfield at Arlanda which is situated some 30 km north of Stockholm.

### *3.4.2 The triage system with RFID technology*

The triage system with RFID technology utilises commercially available low-cost components, including RFID and mobile phone technology. It consists of the following components: the RFID tags, a mobile phone (Nokia 5140i) equipped with an integrated RFID reader/writer, the'mTriage' in software application (Logica CMG Co., Finland) used in triage education and the Nokia SM computer server with a connection to the external IT system that comprises a Merlot Medi® server and software application. The mTriage® software application allows the assignment of each patient to one of the four triage categories. Once a patient is assigned to a triage category, the programme automatically sends a message to the Nokia SM (back end system) and stores it on the patients' personal RFID tag. The server then forwards the data as an in-advance warning to the receiving medical facilities, as well as to the command centre in charge of the situation.

Passive (ISO 14443A) RFID tags with 1 KB of RAM memory were chosen due to the reader being able to provide electromagnetic energy that activates the tag within the reading range of 0–10 cm, hence eliminating the need for an internal power source (e.g., battery) in the tag. A commercial civilian GSM network (TeliaSonera PLCo, Finland) was utilised to communicate with the server (back end system). This technology is not dependent on GSM or any other network technology such as TErrestrial Trunked Radio (TETRA) competence devices.


**Figure 2.** The triage category data entry screen in the Nokia 5140i mobile phone.

The Nokia SM, with specially developed software, was used to authenticate the users of the mTriage® application, i.e., the creator (medics) of the current triage, and to log all RFID tag reading events. It also enabled the casualties' personal medical data to be matched by the Merlot Medi® server with the individual tag identities received from the field. The matched information on the patient was then forwarded over a secure encrypted connection to the computers within the medical facilities and the command centre. The Merlot Medi® end-user interfaces installed on the computers displayed the current number of casualties expected to be evacuated to the specific facilities, as well as the casualties' triage categories and previous medical data (Nokia, 2006).

### *3.4.3 Military field exercise*

The system was tested by the Finnish Defence Force Centre for Military Medicine during a large military field exercise (Pyry 2006) which involved 4000 conscripts and 800 vehicles in the harsh sub-arctic conditions of Central Finland in December 2006.

Of the 45 medics participating in the exercise, 18 were given a personal RFID tag, referred to as Tag A. They also received an RFID reader-enabled Nokia 5140i mobile phone. Similar equipment was provided to seven medical facilities and five evacuation vehicles, with location-specific tags marked tag C. All field medics using the new triage system received a 10 minute instruction session on the use of the system.

The 130 conscripts participating in the study were randomly selected as mock casualties for the study. These conscripts were informed that they had been injured and an injury card describing each individual's simulated injury profile was hung around their necks. An RFID tag, referred to as Tag B (representing a normal soldier's 'dog tag'), was attached to their injury profile cards. The triaging of the mock casualties was based on the injury profile located on their cards. The triage category was changed whenever a patient's condition required it.

The triage workflow began with the field medic reading his own RFID tag (Tag A) by touching it with the mobile phone. This turned on the mTriage® application, authenticating the identity of the medic and allowing the application and the phone to be used for triage. The medic then touched the casualty's injury card (Tag B) with the phone and assigned a triage category for the victim, using the mTriage® application according to the given injury profile. Next, the medic touched the casualty's Tag B with the phone once more, saving the wounded soldier's triage category into the RFID memory. The triage category was then automatically sent by SMS via the GSM network as an advance notice to the medical facility receiving the patient. The information on Tag B could be assessed with readers, even if the GSM network and back end systems totally failed. After first aid, the casualty was evacuated to the Company Aid Station (CAS), where the receiving medic could repeat all the same steps as the medic who sent the casualty's data. By reading the casualty's Tag B, the medic could retrieve and update the casualty's previous triage category when necessary.

A second advance warning was then sent via the Nokia SM to the next medical facility, e.g., the Battalion Aid Station (BAS) or the Evacuation Hospital (EVACH). This process is repeated in the following medical facilities and in the evacuation vehicles along the evacuation chain.

### *3.4.4 Determinations of reliability of RFID*

The first part of the study IV, took place at Lake Vesijärvi in Lahti, Finland 2008. The situation began as a search operation for unexploded ordnance discovered in the lake. During the search, a passenger ship departing from the port had run aground close to the diving site. An emergency call to 112 was made from the passenger ship after running aground. Subsequently, a fire began, mildly injuring 20 passengers on board with eight jumping into the water. Two divers at the same site received other injuries.

Of the simulated patients, eight out of the total 30 aboard jumped off the boat. Nine were classified as seriously injured and ten as mildly injured; five were triage category 1 (Immediate) patients, four were category 2 (Urgent) patients and 10 were category 3 (Delayed/Walking Wounded) patients. In the training exercise, the emergency services rescue department worked in co-operation with the police, Finnish Navy, the Centre for Military Medicine, Emergency Response Centre Administration, Finnish Border Guard, the local lake rescue association, Finnish Red Cross (FRC) and World Wide Fund For Nature.

Twenty RFID –tag patients in the study were given the National Triage Card -tag. Of the 20 patients, five were classified as triage category 1, five category 2 and ten category 3. The final group consisted of 18 casualties in total, because information was lacking from two casualties due to a temporary error. These two casualties were unable to be recorded and hence excluded from the study results.

The second part of the study IV was performed at a major airport in Stockholm, Sweden in 2008, with a large aeroplane disaster exercise (Arlanda 2008). The full-scale major incident exercise involved a simulated passenger airplane crash landing with a total of 99 passengers and crew aboard the airplane.

In Sweden, the Merlot system was used, mainly for metering and situation information purposes. Triage tags and phones were given to each casualty, allowing transmission of each triage performed by the rescue personnel to the triage-service for performance analysis. At the main evacuation hospital and the command center, the triage web was used to display real-time situation information. Typically the triages were transmitted from the scene or evacuation spot, from the airport gate (time stamp on leaving the airport) and on arrival at the evacuation hospital (simulated). The technological suitability of the system for field use was measured by analysing the recorded data transfers, tag events and the number of failed data operations. A total of 17 casualties were RFID tag casualties, all categorised by professional medical staff and given SMART tags, containing a dynamic, high visibility, triage tag. Of these 17 casualties, eight were initially classified as triage category 1, three as category 2 and six as category 3. Six casualties were unable to be recorded and were excluded from the study results.

### 3.4.5 Triage workflow

Once at the disaster scene, the rescue personnel began triage tagging of the casualties with SMART cards. The triage class allocated was then stored by the casualties with triage phones on the RFID tag and sent to triage service. When a new triage-tag identification number arrived at triage service, a new patient record was inserted into the system. All subsequent transactions related to the same triage tag were then associated with this patient record. A clerical officer with triage-PC inserted additional data on the victims and wound types into the patient records.

### 3.4.6 The system process

Based on the near real-time information distributed by the triage service, all participants involved in the evacuation and recovery of casualties could make informed decisions such as:

- Directing ambulances to specific hospitals based on casualty injuries and the number of critically injured victims
- Organising the Emergency Departments (ED) resources to meet the needs of
- Specific patients directed there.

## 3.5 COLLECTION OF DATA

Having attended the 10 minute instruction session and prior to any actual personal and hands-on experience, the users were requested to express their beliefs and personal confidence in the ease of using the RFID reader-enabled mobile phone with the mTriage® software application with a 10 cm Visual Analogue Scale (VAS).

Following the exercise and after two consecutive successfully performed triages, the (Implementing RFID technology in a novel triage system) participants expressed their experienced difficulty whilst using the system on the VAS (VAS 2). A VAS score of 0 represents ‘Using the system was very easy’ and 10 ‘Using the system was very difficult’.

### 3.5.1 Technology

The tested system consists of:

- RFID -read/write capable mobile phones or TETRA -radios with Logica “mTriage” software (triage phone) distributed among the rescue personnel “in situ”, including volunteers (triage personnel)
- RFID-tags attached to “zipper necklaces” (triage tags) for fast and reliable deployment on victims
- Rugged laptop and/or tablet PCs with Logica “Merlot Medi Mobile” software (triage-PC) for clerical officers at the scene or at evacuation and treatment facilities
- A centralised disaster information system, here a Logica “Merlot Medi Server” (triage service)
- World Wide Web (WWW) -pages and means to access it (triage web) for the real time situation information on victims and their evacuation.

The triage mobile phone is intended to be used by all medical rescue personnel, whether professional or volunteer, who are capable of operating an intuitive triage. All victims are tagged “in situ” with triage tags regardless of injury. The triage-PCs enables the input of additional patient data such as personal, injury, evacuation and treatment information by the clerical officers on the scene or along the evacuation process. The triage service receives and distributes the gained information to all necessary levels of management, acting as a centralised storage point for all the information thus providing excellent source material for accurate performance analysis. The triage web is a “read only” website showing real time situation information. It can be accessed via almost any web browser on any computer or smart phone.

### 3.5.2 Selection and procedure in PYRY2006 in Finland (Study III)

The Finnish Defence Forces Centre for Military Medicine additionally had extensive and thorough procedures in place in relation to the selection and profiling of the mock casualties. The 130 mock casualties participating in the study were conscripted to the study trough a random selection process. They were informed that they had been injured and an injury profile was hung around their necks. Additionally, a RFID tag (referred to as Tag B representing a normal soldier`s dog tag) was attached to their injury cards. Furthermore the triaging of the mock casualties was based on the injury profile stated on their injury cards.

### 3.5.3 Technology process

Once at the disaster scene, the triage-personnel began to perform intuitive triage and triage tagging of the casualties. The triage class allocated was stored on the tag and sent to triage service with the triage phone. When a new triage tag identification number arrives at triage service, it inserts a new patient record into the system. All subsequent transactions related to the same triage tag are then associated with this patient record. Ideally the triage team responsible consists of several medics carrying out evacuation procedures. In the future development of the technique also additional data on the victims and wound types could be inserted into the patient records via the triage phone.

Based on the near real-time information distributed by the triage service, all participants involved in the evacuation and recovery of casualties can make informed decisions such as directing the ambulances to specific hospitals based on the casualty's injuries and the number of critically injured victims, as well organizing the Emergency Department (ED) resources to meet the needs of the specific patients directed there.

### 3.5.4 Test setting in Lahti, Finland (Study IV)

The first part of the study took place at Lake Vesijärvi in Lahti, Finland, on the 27th of September 2008. The situation began as a search operation for unexploded ordnance discovered at the bottom of the lake based on gathered information. In connection with the search, a passenger ship departing from the port runs aground close to the diving site. In the aftermath of the grounding, emergency services professionals rescue both floating and injured passengers. Of the simulated patients, eight out of the total 30 aboard the boat had jumped off the boat. Nine were classified seriously injured and ten mildly injured - five were triage category 1 (immediate) patients, four category 2 (urgent) patients and 10 category 3 (delayed/walking wounded) patients. Participating in the training exercises was the emergency services rescue department, in national collaborationist i.e. the Police and Finnish Defence Forces.

A medical personnel likely to be at the scene was issued a number of triage tags and a triage phone. Personnel included triage doctors and nurses as well as conscript military medics, FRC volunteers and airborne-rescue unit medics. Training in the use of the triage phone simulated a real life situation where the equipment needs to be deployed en route to the disaster scene. Hence, on average, personnel involved had a short explanation on the usage of the system and several minutes to practice, before reaching the disaster area. Initial triage classifications came from conscript military medics attending to victims already ashore. Soon after, triage data from those aboard the passenger ship was recorded by airborne medics, who had descended from helicopters onto the ship. This information only included the triage tag identification number, triage class, time stamp and medic identification, the latter also informing where the triage was performed. The triage information and other tag information (ambulance and position data) were transmitted from the Security Authorities Network (TETRA).

Whilst this was occurring, military medics established a Battalion Aid Station (BAS) ashore at the nearest possible landing site. The BAS commander was also the doctor responsible for triage. The commander had a clerical officer with triage-PC present to inform them of the overall situation as well as inserting additional victim and injury data into the patient records. Both were officers of the Finnish Military Reserve.

One mission of the Finnish Defence Forces (FDF) is to support other national authorities in disaster or mass casualty situations. The FDF is prepared to make statutory or collaborative agreements on assistance and other support to all levels of society. In a disaster situation involving civilians, general management is performed by the rescue authority. Medical responsibility for leading an event such as a large scale accident is the duty of the health authority.

### *3.5.5 Test setting in Arlanda in Sweden (Study IV)*

The second part of the study was performed at a major airport in Stockholm on the 9th of October 2008, with a large aeroplane disaster exercise (Arlanda 2008) in the harsh sub-arctic conditions of Sweden. The full-scale major incident exercise involved a simulated passenger airplane crash landing with a total of 99 passengers and crew aboard the airplane.

Of those victims, 20 patients were selected as “RFID patients” for the study. Each injured casualty had a descriptive card describing their simulated injury profile which was hung around their neck. After the simulated casualties were triaged, each received a triage card. Triage of the simulated casualties was based on the injury profile shown on their card. An RFID tag was attached to their triage card. The system was the same as the one used in the simulated disaster in Finland except for the fact that the simulated casualty sends the information via the triage phone. The purpose was to transmit the triage category of the patient to all levels of management with the intention to higher situational awareness.

The management of the disaster was achieved by the means of several hierarchical management levels. The highest, the strategic or 'gold' command, was activated by a mass casualty warning and manned in a special location away from the actual incident, in this exercise it was the Emergency Medical Command Centre SOS Alarm. The dispatch centre referred the injured to three receiving hospitals in the region; one of the hospitals acting as the target hospital. Situational awareness on all management levels was dependent on information that was sent from the airport using various telecommunication methods.

The technological suitability of the system for field use was measured by analysing the recorded data transfers, tag events and the number of failed data operations.

In Sweden, the Merlot system was used mainly for metering and situation information purposes. Triage tags and -phones were given to each patient for transmitting each triage performed by the rescue personnel to the triage service for performance analysis. The triage web was also used to display the situation information at the main evacuation hospital and the command centre. Typically triage data was transmitted from the scene or evacuations spot, from the airport gate (time stamp leaving the airport) and when arriving at the evacuation hospital (simulated).

# 4. STATISTICAL METHODS

The statistical methods used in the study of LT and ILMA techniques by short video clips (I) were varied, with numerical data presented in the results being median values, if not stated otherwise. The 95% confidence intervals (CI) were calculated using the modified Wald method. Fisher's exact test and the Mann-Whitney test were used to analyze differences between groups, A *p*-value $X^2$ 0.05 was considered significant and was used as an appropriate GraphPad Prism version 4.0a for Macintosh (GraphPad Software, San Diego,CA).

In the study of a mobile medical information system (II), the statistical analysis was performed using StatView 4.5. Potential differences in their behaviour over the three points in time were tested by ANOVA (Sig. $< 0.05$). The Scheffé test was used for *post hoc* tests.

Implementing RFID technology in the triage system (III) required the GraphPad Prism (version 4.0a) program for Macintosh (GraphPad Software, San Diego, California, USA). Approximate 95% Confidence Intervals (CI) were calculated using the modified Wald method. A p-value of less than 0.05 was considered significant. The Wilcoxon-matched pair-signed rank test was employed for analysing the differences between before and after the system was used.

In the study of RFID technology in mass casualty situations (IV), all the data collected from the test was entered in spreadsheets using Microsoft Excel and statistical analysis and was performed using the statistics program SPSS for Windows (Rel. 17.0. 2008. Chicago: SPSS, USA).

# 5. RESULTS

## 5.1 USE OF THE LT AND THE ILMA AFTER A SHORT VIDEO-CLIP TEACHING (STUDY I)

The goal of performing 10 consecutive successful insertions was attained by all 30 subjects (100%) in the LT group and by 27 (93.1%) of the 29 subjects in the ILMA group (p = 0.682). In the first attempt of 10 consecutive successful insertions, 29 (96.7%) of the 30 subjects in the LT group succeeded in inserting the device, whilst 20 (74.7%) of the 29 subjects in the ILMA group managed successful insertions. In the other cases, the series of 10 consecutive insertions was preceded by 1 to 10 failures (Table 6). The mean total time for a successful insertion in the LT group was 22.0 seconds (range 14–29 seconds) and in the ILMA group 23.9 seconds (range 7–67 seconds) (p = 0.459).

**Table 6.** Number of insertion attempts in the LT-group (n=30) and the ILMA-group (n=29) prior to accomplishing 10 consecutive successful insertions.

| | LT | | ILMA | |
|---|---|---|---|---|
| Attempts | n | per cent | n | per cent |
| 1 | 29 | 96,7 | 20 | 74,1 |
| 2 | 1 | 3,3 | 3 | 11,1 |
| 4 | -- | -- | 1 | 3,7 |
| 8 | -- | -- | 2 | 7,4 |
| 11 | -- | -- | 1 | 3,7 |
| Total | 30 | 100 | 27 | 93,1 |

The mean intuitive VAS score for the presumed difficulty of use, after seeing the video clip was 5.1 cm (range 0–10 cm) for the LT and 5.0 cm (range 0–10 cm) for the ILMA. The corresponding median values were 5.0 cm and 5.0 cm, respectively (p = 0.873).The mean value of the VAS score for the perceived difficulty of use after personal hands-on experience and completion of the required 10 consecutive successful insertions, was 0.8 cm (range 0–4.7 cm) in the LT-group and 0.45 cm (range 0–2.5 cm) in the ILMA-group. The respective median values were 3.0 and 2.5 cm (p = 0.466). Two subjects in the LT group and one in the ILMA-group failed to submit both their VAS scores.

## 5.2 BEHAVIOUR DIFFERENCES OF THE USE OF MOBILE SYSTEMS AMONG STUDENTS (STUDY II)

The two groups of users shared fairly similar perceptions on the important features of the mobile system with relative differences below 5%, which was at the significant level.

Figure 3 shows the results of the comparison. The left Y-axis indicates the numerical scale we adopted in the analysis. The right Y-axis was the percentage we used to show the relative difference between the two groups. The significance level was set at 0.05, which was 5%.

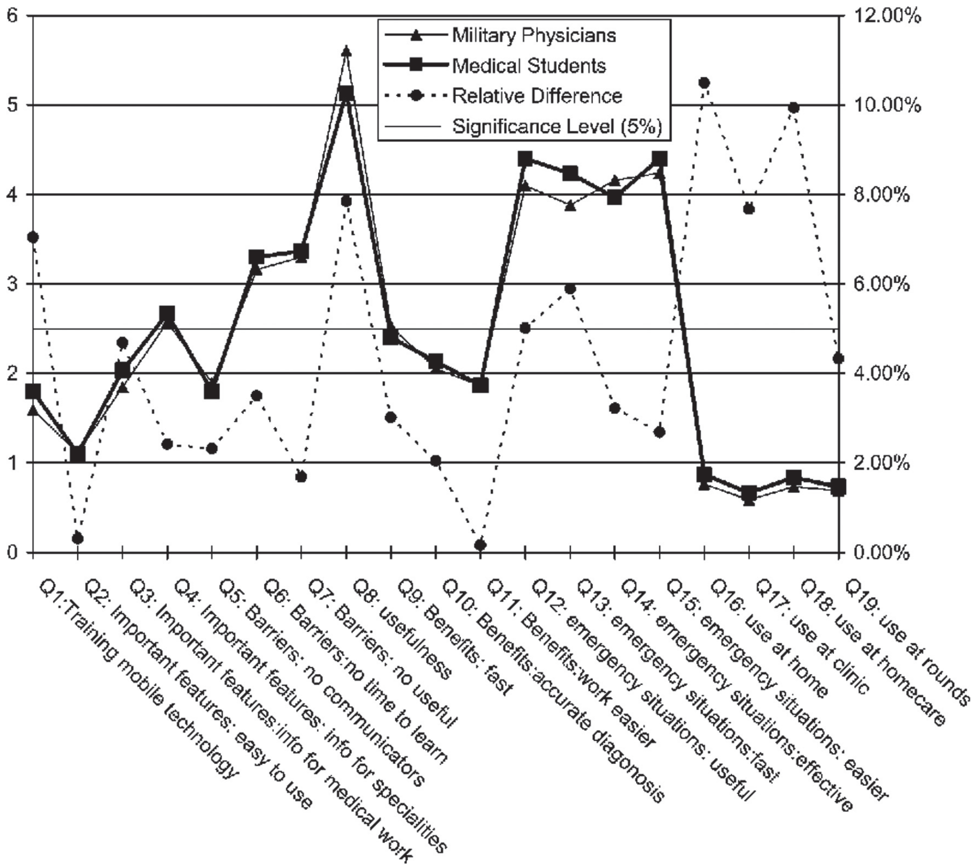



Figure 3. Behavioural differences between the two groups.

Since the survey for the medical students was implemented after use of the mobile system for approximately three months, it is not surprising to find out that they received slightly more training on the usage of mobile technology in the past year than the MOs.

Ease of use, information for medical work, and information for specialties were all considered as important features with the average scores below 3 but with ease of use being one of the most important.

The mobile system being "useless" and "having no time to learn its usage" were not regarded as barriers in the use of the system in both groups. Comparatively, not owning a communicator, the mobile platform for running the system, was pointed out as a barrier with the average score slightly below 2. The possible reason is that the communicator is a relatively expensive device for the groups to buy in order to use the mobile system. In general, the two groups showed similar views of the barriers in implementing the mobile system.

Both groups have indicated that the mobile system was useful with the average scores above 5 although the MOs ranked it slightly higher. The relative difference between the two groups is above 5% and therefore slightly significant. The difference was most likely due to the MOs' lack of access to other databases when working in the field or in garrison. Thus, the mobile system gave an alternative for them to access medical knowledge and information under these unique circumstances.

Both groups agreed that by using the mobile system facilitated their work and this factor was listed as the most important advantage with the average score below 2 (agree-fully agree). The two other advantages: by using the mobile system, work would be speeded up and would provide accurate diagnosis, achieved a score of 2–3 (agree-neutral). In general, the results have shown that the mobile system brought some degree of benefit for the group's work either in the campus or in military environments. The relative differences between the groups were very marginal, below the significance level 5%.

The two groups believed that use of the mobile system in emergency situations may not be useful, or not make work faster, more effective or easier with average scores from 4–5 (4 being the lowest degree). Scores from the medical students were slightly more positive than those of MOs, especially when asked if the mobile system would make their work effective in emergency situations.

The two groups liked to use the mobile devices for searching medical information in many environments but seemed to behave differently when use occurred at home, in the clinic or homecare, with relative differences above 5%.

## 5.3 IMPLEMENTING RFID TECHNOLOGY IN TRIAGE SYSTEM (STUDY III)

During the large military exercise, a total of 579 tagging events were recorded, comprising 147 (25.4%) A Tags (identification) and 432 (74.6%) B Tags (operative). One patient was involved in 11 tagging events; the highest recorded number of tagging events of a single patient.

## 5.4 POTENTIAL OF RFID TO PROVIDE REAL-TIME OVERALL SITUATIONAL AWARENESS (STUDY IV)

*Situational awareness timeline in Finland*

A call to emergency services (112) was made from a passenger ship after running aground. Subsequent damage instigated a fire, mildly injuring 20 passengers on board and causing eight to jump into the water. Two divers at the same site received other injuries. By 10:45am the Battalion Aid Station (BAS) had treatment capabilities; receiving the first two patients, who were divers injured during a search operation. One experienced decompression sickness, whilst the other had an injured limb. One patient was triaged as triage category 2, with the other triaged as category 1 and evacuated to the University Hospital of Turku to receive hyperbaric oxygen therapy. Both casualties were evacuated in time by 10:36. Four ambulance patients (triage category 3) arrived next to the BAS, followed by three patients recovered by the rescue helicopter. The next batch of five patients consisted of four ambulance (triage category 3) and one stretcher case (triage category 2). The last five patients arrived shortly after, consisting of one ambulance and four stretcher-bound patients. All patients, except one were evacuated from the BAS to Päijat-Häme Central Hospital.

The total number of 20 RFID –tag patients had been given the national triage tag. Of the 20 patients, five were classified as triage category 1, five category 2 and ten category 3. Control group patients (N=18) consisted of five triage category 1, five triage category 2 and eight triage category 3 casualties. Two patients were unable to be recorded and hence excluded from the study results. The average time difference in the BAS between the national triage tagging and RFID's on receiving data was 47 minutes.

Towards the end of the evacuation a situation occurred where one of the yellow (2nd priority) patients was re-triaged red (1st priority) and all the nearest emergency rooms were already overloaded with patients. As this information was available at the scene, the triage officer in charge ordered the patient's evacuation to another hospital outside the city.

Several hours after the simulation concluded, two "run-away" triage green victims were found nearby and were easily recognised by the tags hanging on their necks. After they were fed into the system with the triage phone the records were complete and no casualties were lost.

### *Situational awareness timeline Sweden*

The exercise began at 10:20 am when the SOS-Alarm emergency line alerted the duty officer at the Stockholm county council. A commercial passenger airplane with 99 passengers and crew onboard crashed as it attempted to land at 10:20. The Regional Distaster Medical Administration (RKML) was put on disaster status.

By 10:20 am spontaneous evacuation began from the airplane and at 10:24 first aid was initiated by fire department personnel. The first ambulance arrived at the scene at 10:30 and established its presence as the medical incident officer. The 29 casualties were classified as triage categories 1 and 2, 61 as category 3 and nine were classified as dead. The first transports of casualties to receiving hospitals took place at 10:46 and the last patient left the crash area at 12:55. During the exercise, communication difficulties resulted in inappropriate information to the strategic level of management. Lack of real-time information from disaster site delayed the decision making for EDs to coordinate staff and resources in the hospital.

A total of 20 patients were RFID –tag patients, who also had been given the Smart Tag™. Of these 20 patients, only 17 patients were sent to the exercise target hospital. Of these 17 patients, eight were initially classified as triage category 1, three as category 2 and six as category 3. Six patients could not to be recorded and were excluded from the study results. Control group patients (N=9) consisted of six triage category 1 and three triage category 2 casualties. Mean time difference between the Smart Tag® and the RFID was 68 minutes.

The system users found the RFID mobile system sufficiently easy to use and did not consider it more arduous to use than using the traditional paper tags.

The users also found the system supported their work and was not more time consuming than traditional methods.

# 6. DISCUSSION

## 6.1 THE IMPACT OF MULTIMEDIA AND A MOBILE INFORMATION SYSTEM IN MEDICAL TRAINING

A new method of education for medical training of NCOs that is both fast and effective is the use of multimedia presentations, which can even be made to mobile phones. When there is less time to teach, new methods of teaching and bringing knowledge into real situations for the user must be sought.

Rarely used skills are known to deteriorate, and during an airway emergency, there is no time to seek help when there is a great distance to the nearest hospital or doctor. In a previous study the number of insertion attempts and insertion times of 32 inexperienced paramedical students was recorded for the LT and the ILMA, as well as the CobraPLA (COB; Engineered Medical Systems, Indianapolis, IN), in a series of consenting patients (ASA I–II) (Kurola et al. 2006). At the first attempt the ILMA was inserted successfully by 75%, the LT by 44% and the COB by 22% of the students. However, in the present study, the LT was inserted into a mannequin at the first attempt by 96.7% and the ILMA by 74.1% of the trainees. In addition, the mean insertion time for the first of the 10 consecutive successful insertions was shorter with the LT than with the ILMA (22.0 and 23.9 seconds) compared to the respective 24.9 and 22.9 seconds in the study by Kurola et al in 2005. However, results in the study presented here were parallel to the results achieved by Kurola 2006.

Initial insertion success rate was higher with the LT in the current trial. The mean VAS scores for the two devices for the perceived ease of use given by trainees after completion of the required 10 consecutive successful insertions (0.82 for the LT and 0.45 for the ILMA) show that supraglottic devices are well-accepted by inexperienced personnel. The LT and the ILMA are devices that can be used as alternatives for endotracheal intubation and mask ventilation.

The study by Kurola et al. 2006 where human test subjects were used shows that inexperienced users can insert a LT and the ILMA with a good success rate in simulated scenarios with a mannequin along with producing acceptable ventilation parameters. The results of the present study demonstrate beyond any doubt, that even short video demonstrations can provide sufficient practical information and instructions for the application and use of new or unfamiliar devices and with which the spectator has had no personal hands-on experience. Moreover, such videos can well be used even for self-training and be viewed as many times as necessary.

Mobile training can be seen as a form of learning that takes place in authentic environments such as in transit or in the field, with help of mobile technology. Development of educational technologies like learning environments based on GSM phones, PDA:s and laptop computers creates new possibilities for training in military surroundings.

The new technologies enable making learning a part of everyday activity and bringing it directly to the military environment, making the conscripts committed to studying. Educational use of mobile technology has thus far been hampered by the fact that developing mobile learning applications and materials requires a combination of pedagogic and technological expertise.

Our findings confirm that the two groups, medical officers and students, were found to have similar those towards the mobile system in different contexts the similarity of the behavioural patterns suggests that it would be possible to develop a universal teaching tool for both military and civilian environments. The contents of such a system should be made to fit the special needs of military training as well as traditional civilian medical education.

## 6.2 THE IMPACT OF MOBILE PHONE TRAINING IN THE USE OF A NOVEL TRIAGE SYSTEM DURING A SIMULATED MASS CASUALTY SITUATION

Resource allocation in mass casualty situations is a significant logistical problem, both in military and civilian environments. In the military domain and particularly under rapidly changing conditions, reliable and timely situational awareness is crucial for making correct decisions on the allocation of the available resources.

Without situational awareness, the likelihood that wrong decisions are made by the Rescue Operation Command increases and is likely to lead to the suboptimal use of available resources and inferior care of the casualties. Situational awareness is vitally important in civilian circles in cases of accidents or disasters involving greater numbers of casualties requiring help within a limited geographical area, for instance, in bus or train accidents.

Mobile technology has already previously been offered as a major resource for streamlining and emphasizing the processes of emergency and disaster medicine (San Pedro et al. 2004). In this respect, a novel aspect of the present study was the successful application of emerging new mobile technologies. This was achieved by utilising commercial off-the-shelf hardware and a public and commercial GSM network (TeliaSonera, Finland). It achieved a functional and dedicated emergency medical communication system for delivering real-time data from the field, as suggested by Lenert et al. 2005 and by Killeen et al. 2006. Testing the applicability and reliability of the new system thus constituted an integral part of the aims. These aims were to update and increase the functionality and effectiveness of the present by military medical responses provided by the military medicine of the FDF, as well as response's potential applicability for the civilian sector.

RFID is a quickly embraced, convenient and easy to use means of identification and it is also applicable to automatic operations. Moreover, it combines advantages that are not available in other identification technologies. RFID can be supplied both as read-only or read/write chips. It does not require direct contact or line of sight in order to function and it also functions under varying environmental conditions, maintaining excellent data integrity.

As the technology is difficult to counterfeit, RFID also provides high levels of security (Intermec 1999). The protection of the tags' privacy is achieved by the prevention of unauthorised reading and the blocking or jamming of electric waves (Ohkubo et al. 2005). Due to the high demands on data security, both the technology and data stored in the RFID tags must be absolutely secure. In the present study, security has been guaranteed by very close range reading of the tags, providing protection against possible electronic interference. Only the serial number is stored on the tags and the rest of the necessary data was obtained from a server.

The system presented here has clear advantages over the traditional method of using paper cards attached to the patients. A paper card is cheap to buy but can be easily destroyed or lost. Paper cards can have classic problems such as bad handwriting and missing information. Any electronic system should be able to solve these problems.

The novel aspect of our system, using commercial products and networks in combination with some tailor-made parts, is a cost-effective way to introduce new technology to the field. However, the commercial parts of the system do have some drawbacks. First, the terminal device is not particularly durable and might break easily. The size of the device may even be a problem – the device is easily lost. The chosen data carrier, a commercial GSM network, is easily jammed or destroyed in a military crisis. However in a civilian mass casualty situation, the text message gateway has proven to be one of the most robust and reliable communication networks.

The system addresses the problems in delivering situational awareness higher in the command chain. In this respect, the system performs its tasks well. However, as the RFID tag can only be read with a reader, the status of a patient is not clearly visible, as is the case with colour-coded paper cards.

The findings of our studies do provide some guidance for designing the next generation of field medicine management systems, even if further studies with alternative technologies are still needed. However the policy of training is a difficult issue, because no widely accepted standard has yet been used.

The mTriage® and Merlot Medi® based solutions offer several clear advantages over traditional methods. The most important is the real-time information on casualties and the overall situation. This is the primary information used to determine the troops' combat capability, as well as the load placed on medical facilities and evacuation chains. Based on this information, the medical resources and the casualties can be optimally allocated. Access to the information is another important feature. When the information on the medical/evacuation situation is distributed towards the frontline (via mobile devices), the medical personnel in the field can better estimate the future patient load up the evacuation chain and can therefore distribute the patients accordingly. This avoids congestion in the receiving medical facilities.

Under all conditions, the use of limited and precious resources must be optimised to provide the maximum benefit to the largest possible number of casualties. In mass-casualty situations involving extensive areas, only the ability to collate information on the number of casualties and their triage categories, in different regions of the area, makes efficient and optimal use of limited rescue capacities possible.

The direct cost of RFID solutions is one of the key barriers to the large-scale application of this technology in healthcare. However it is widely believed that the prices of RFID tags, both passive and active, will fall substantially in the near future (Harrop and Das 2009). Similar assumptions are made about complete RFID applications, including tags, infrastructure and middleware/hardware, although the size of the cost decrease and its timeline are somewhat ambiguous.

The RFID systems do have their own weaknesses. An obvious weakness is the need for a reader to access the information. Another issue is data ownership and security. While the threats current healthcare RFID applications face are not as potentional as occasionally publicly portrayed, they are real and potentially disabling for open-loop RFID applications. There has been continuous debate over what kinds of access rights there should be, for whom and how they should be guaranteed, in the healthcare and policy-maker communities (Fisher and Monahan 2008).

As the results show, the RFID triage system is effective in mass-casualty incidents of even 100 casualties. In the future, the system will be more valuable when it becomes applicable for other incidents, such as situations with smaller numbers of casualties or in disasters affecting large areas, such as earthquakes or storms (Inoue et al. 2006).

Novel information technology applications affect the emergency care organisation's work processes and collaboration between organisations. In implementing new information technology applications, it is not enough that only medical personnel learn to use new equipment. The programme should be implemented in medical care curriculums using novel information technology. In considering the potential applications of any single device, focus should be placed on product development. Technological innovation in medical care is a particular challenge. Technological innovation also requires social innovation. Novel medical care information technology projects and the introduction of technology are not the starting point, but training and medical services should be at the forefront in the development of technology.

New information technology will not replace face-to-face training but should accelerate the learning processes. New "virtual technology "is also part of military training and continued development of it is strong throughout. For the mTriage training can be given in real military exercises by using simulated mass casualty situation environments.

There are numerous trends in new information technology, many of them left unmentioned in the present study, which can lead us towards a better understanding of new technology and by extension, their improvement. In military medicine and mass casualty situations, setting the focus on the task through "thinking globally and acting locally" (Leppäniemi 2004) seems to be applicable. This is also the case in education. Research and development of educational technology is an important prerequisite for developing functional mobile learning applications. The benefits of mobile learning such as independence of time and location are obvious. However, to create actual applications, a solid base of knowledge is required concerning the added value and learning enhancement provided by mobile systems, as well as about how learning is supported in other or mobile learning environments.

The selection of a particular training strategy hinges on factors such as effectiveness and costs. It is unlikely that any single training strategy will satisfy every individual and team training need. Instead, it is essential that a combination of strategies be used.

## 6.3. LIMITATIONS AND STRENGTHS OF THE STUDY

The studies presented here have several limitations. Studies done using simulations never fully reflect real situations. The first limitation of study I is that results from simulations with mannequin may not be directly applicable to clinical patient management. Human anatomy varies from person to person and although the ILMA and LT were used successfully in this test situation, the devices might perform differently in real subjects. A good example is in a real situation, where the size of a tube has to be chosen correctly from three adult versions. Also the risk of aspiration cannot be evaluated using a mannequin and the limited number of insertions has to be taken into account, when interpreting the present results (Kurola et al 2004).

During the Arlanda exercise there existed a qualitative limitation since triage was made by patients involved and not by professional medical staff, a decision that was made by local authorities.

Environmental pressures also affect performance. In real emergency situations, the situation itself may be more mentally exhausting than its simulation. An example in a real situation is that the medic or person helping, might not necessarily be able to follow instructions as well as those given during a simulated event. Some test subjects experienced the effect that an extensive simulation had on nervousness and therefore, felt more nervous than in a real situation (Harve 2009).

The strengths of the study presented here are in that the population used was mostly conscripts and voluntaries and thus highly skilled and careful. Moreover, the population will be trained for components of wartime readiness.

# 7. CONCLUSIONS

1. No absolute superiority of the LT or the ILMA could be demonstrated with respect to their applicability for emergency airway management. Hence, both the LT and ILMA provide important alternatives to face mask ventilation for non-professional, emergency medical personnel. The results of the present study strongly support the incorporation and continuation of the applied method = support for incorporating and continuing the application of the approach used here. That is short video clips, as an integral routine component in the education and training in basic life support of medical NCOs as first responders in the Finnish Defence Forces.

2. The results of our studies show that there appears to be a general need for mobile information system to be further developed. The different environments where medical practice took place, a civilian university campus and a military environment, seemed not to be a crucial factor in having an impact on the two user groups behaviour. It seems to be possible to develop universal tools that can be used in a wide range of contexts, although the contents of the system should be updated and supplemented to suit the needs of military medicine. The study suggests that handheld computers are an important and evolving part of the resources of both in medical training.

3. The presented RFID system was easy to use as a triage tool for medical personnel. The technology was applicable for distributing real time triage information in a simulated mass casualty situation.

4. The tested system allowed optimisation of resources in a mass casualty scenario by providing reliable real-time overall situational information to those overseeing the rescue operation. Situational awareness in all hierarchical management layers was based on common data generated in real time at the incident scene. The timeliness of available information for disaster management was significantly better using the RFID/Merlot Medi®-system than with the traditional methods.

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ORIGINAL RESEARCH

# Laryngeal Tube and Intubating Laryngeal Mask Insertion in a Manikin by First-Responder Trainees after a Short Video-Clip Demonstration

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**Keywords:** airway management; emergency care; first responders; intubating laryngeal mask; laryngeal tube; manikin study; military paramedics; resuscitation; training; video

**Abbreviations:**
FDF = Finnish Defense Force
ILMA = intubating laryngeal mask
LMA = laryngeal mask airways
LT = laryngeal tube
VAS = visual analogue scale

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**Abstract**

**Introduction:** This study was performed in the Finnish Defense Forces to assess the potential applicability and value of short video clips as educational material to teach advanced airway management and as the first means of introducing the use of a laryngeal tube (LT) or an intubating laryngeal mask (ILMA) to inexperienced, military, first-responder trainees with no prior hands-on experience.

**Methods:** The 60 non-commissioned medical officers participating in this study were randomly assigned into one of two groups: the LT- and the ILMA-group. After viewing the video clips, the trainees were required to perform 10 consecutive, successful insertions of the given instrument into a manikin. The number and duration of the attempts required prior to the 10 consecutive successful insertions were measured.

**Results:** The goal of 10 consecutive successful insertions was attained by all 30 subjects in the LT-group, and by 27 of 29 subjects in the ILMA-group with a maximum of 30 attempts. Improvement in the ease and speed of insertion was evident between the first and last consecutive insertions in both groups.

**Conclusions:** "Satisfactory" to "good" skill levels are achieved with the applied video-clip demonstration method, even in inexperienced first-responder trainees lacking previous hands on experience.

**Jokela J, Nurmi J, Genzwuerker HV, Castrén M: Laryngeal tube and intubating laryngeal mask insertion in a manikin by first-responder trainees after a short video-clip demonstration.** ***Prehospital Disast Med*** **2009;24(1):63–66.**

## Introduction

Establishing and securing an open airway plays an integral part in basic life support. The cuffed endotracheal tube remains the golden standard for restoring and maintaining adequate blood oxygenation to patients in respiratory distress. However, endotracheal intubation only can be used by experienced personnel.[1] Ventilation with a facemask also can be applied, but several potential risks, including over-ventilation with gastric inflation and subsequent regurgitation, must be taken into consideration.[2]

To overcome the difficulties and risk factors associated with intubation and face masks, oropharyngeal airways such as the Combitube® (Tyco Healthcare/Sheridan, Argyle, NY), laryngeal tube (LT) (VBM, Medizintechnik, Germany) and the intubating laryngeal mask airway (ILMA) (LMA-Fastrach™, LMA North America, Inc. San Diego, CA) have been developed. These devices are inserted blindly into the patient's oropharynx.[3–6] The devices in this study, the LT and the ILMA, were chosen for their superior simplicity of use by non-trained personnel as compared to the Combitube.

The LT, a device somewhat like a single-lumen, shortened Combitube® was introduced in 1999.[5–7] An identical, polyvinylchloride (PVC) version of the LT for single use has been available since 2004.[8] It has two cuffs that are inflated with a single syringe. The distal cuff lies at the orifice of the esophagus and the proximal cuff blocks the pharynx at the base of the tongue.

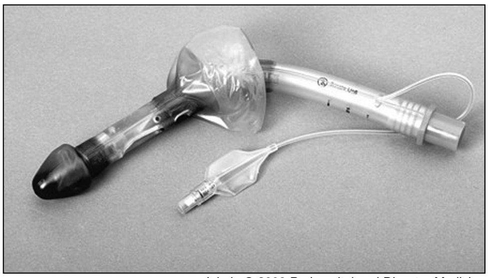

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**Figure 1**—Disposable laryngeal tube (LT)

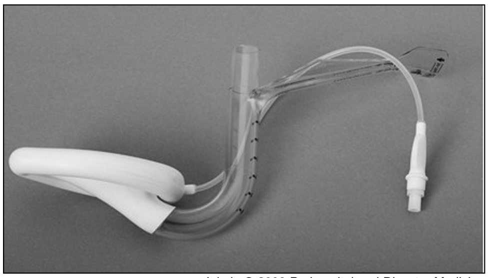

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**Figure 2**—Intubating laryngeal mask airway (ILMA)

Between the two cuffs, there are two apertures through which air enters the lungs via the larynx.

The original laryngeal mask airway (LMA), also known as the classic LMA (invented in 1981), was modified in 1988 by adding an inflatable cuff and using latex and silicon. It gained vast success in UK hospitals in 1989 and was approved by the US Food and Drug Administration in 1991.[9] The classic LMA is recommended by the European Resuscitation Council.[10] The ILMA (LMA-Fastrach™), a variant of the LMA, was introduced in 1973,[4] and it has been studied mainly in the context of difficult intubations.[10] Compared to the standard LMA, it is inserted without digital manipulation and is designed to be used with the patient's head and neck in the neutral position and the cervical spine immobilized. The ILMA also allows blind or fiberoptically conducted tracheal intubation without removing it.

In the Finnish Defense Forces (FDF), the total service period for conscripts becoming non-commissioned medical officers is 362 days. The first eight weeks consists of basic training. After basic training, they participate in a three-month period of education and practical training in first aid and basic life support in the FDF Medical School. After graduating from the Medical School, the non-commissioned officers return to their own units where they practice and improve their skills in first aid and basic life support by working at the FDF's health officers. By working at the FDF health office's bureau, they also participate in martial training in the field and camps, where manikins are, as a rule, employed in simulated situations. The standard airway management has been head-neck-tilt, oropharyngeal airway, and mouth-to-mouth ventilation, if needed.

The aim of this study was to investigate the applicability of the LT and the ILMA as the first airway management instruments for use by inexperienced military trainees in the FDF Medical Corps. The instruments were used by novice trainees after viewing a short video-clip teaching the proper insertion technique. Both LT (Figure 1) and ILMA (Figure 2) are supraglottic devices inserted blindly into the patient's oropharynx. These investigations are only one part of a larger project at the FDF's Centre of Military Medicine for further improving the level of education and practical skills of the conscript trainees during their time of military service.

## Methods

Sixty volunteer conscripts (56 males and 4 females) 18–21 years of age at the Non-Commissioned Officers' School of the Cavalry Battalion in the Hame Regiment participated in the present study after receiving 50 hours of training in first aid and basic life support. The conscripts were randomly assigned into one of two separate groups: 30 to the LT and 30 to the ILMA group. Prior to initiation of the actual study, there was one dropout in the ILMA group.

The subjects in the LT group were shown a 35-second video-clip demonstrating insertion of the LT and the inflation of its cuffs. The subjects in the ILMA group were shown a 20-second video-clip on the insertion of the ILMA. Both the LT and the ILMA video clips were shown without audio comments. The respective video clips were shown only once and just before the insertions were performed by participants of both groups.

After viewing the video clip and prior to any personal hands-on experience, the participants in both groups were requested to express their subjective opinion on the ease of performing a successful insertion on first attempt using a 10 cm visual analogue scale (VAS). The scale ranged from "I believe I can use the instrument" to "I believe I can not use the instrument". A score of 0 indicated the greatest confidence and a score of 10 the greatest doubt in one's own personal performance. After completion of the required series of insertions, the experienced difficulty in using the device was measured with a 10 cm VAS ranging from "Using the device was very easy" to "Using the device was very difficult".

The settings in the test room were identical for both groups. A Resusci® Anne Simulator (Laerdal Medical AS, Stavanger, Norway) was placed on the floor; its airway was prelubricated with a water-based gel.

In the LT group, a completely deflated laryngeal tube (size 4; for adults weighing 50–70 kg/110–154 lbs) was placed next to the manikin's head and the color-coded 100 ml filled syringe was located on the opposite side. Similarly, in the ILMA group, a completely deflated, intubating laryngeal mask airway (ILMA, size 4) was placed next to the manikin's head and the 20 ml filled syringe on the opposite side.

During the testing, the participants were not permitted to watch each others' performances, nor were they allowed to communicate with each other until the end of the test series. Moreover, they received no information on their personal performance times or the level of effectiveness prior to completion of the whole test series by all participants.

Performance times were measured starting from the moment the LT or the ILMA was picked up and ending when the syringe was laid down after cuff inflation. These

| | LT | | ILMA | |
|---|---|---|---|---|
| Attempts | n | % | n | % |
| 1 | 29 | 96.7 | 20 | 74.1 |
| 2 | 1 | 3.3 | 3 | 11.1 |
| 4 | -- | -- | 1 | 3.7 |
| 8 | -- | -- | 2 | 7.4 |
| 11 | -- | -- | 1 | 3.7 |
| Total | 30 | 100.0 | 27 | 93.1 |



**Table 1**—Number of insertion attempts in the laryngeal tube (LT) group (n = 30) and the Intubating laryngeal mask airway (ILMA) group (n = 29) prior to accomplishing 10 consecutive successful insertions

times were registered by an independent observer. Insertion of both the LT and the ILMA was judged by an instructor as "successful", when a tidal volume of at least 400 ml was achieved. According to Dörges *et al*, this is the amount that doesn't result in gastric insufflation with a bag-valve device.[5]

Intuitive ease of use was assessed by counting the number of attempts needed by each subject before the first successful insertion of the instrument. For the evaluation of repetitive insertion, the participants had to perform 10 consecutive successful insertions. Before each insertion attempt, the test conditions were the same as at the beginning of the trial. When an insertion attempt failed, counting was restarted from the beginning until a series of 10 consecutive successful intubations were accomplished. The numbers of failed attempts prior to the 10 consecutive successful insertions of the LT or the ILMA, as well as the execution times of each individual insertion, were recorded.

Statistical processing was performed using GraphPad Prism version 4.0a for Macintosh (GraphPad Software, San Diego, CA). The numerical data presented in the results are median values if not stated otherwise. The 95% confidence intervals (CI) were calculated using modified Wald method. Fisher's exact test and the Mann-Whitney test were used to analyze differences between groups, as appropriate. A $p$-value ≤0.05 was considered significant.

**Results**

The goal of performing 10 consecutive successful insertions was attained by all 30 subjects (100%) in the LT group and by 27 (93.1%) of the 29 subjects in the ILMA group ($p$ = 0.682). On first attempt at 10 consecutive successful insertions, 29 (96.7%) of the 30 subjects in the LT group and 20 (74.7%) of the 29 subjects in the ILMA group succeeded in inserting the device (Table 1). In the other cases, the series of 10 consecutive insertions was preceded by 1 to 10 failures. The mean total time of a successful insertion in the LT-group was 22.0 seconds (range 14–29 seconds) and 23.9 seconds (range 7–67 seconds) in the ILMA group ($p$ = 0.459). Insertion times were ≤10 seconds in 102 (34%) of the 300 successful insertions in the LT group and in 155 (57.4%) of the 270 successful insertions in the ILMA group. Correspondingly, the insertion times were >10 seconds in 198

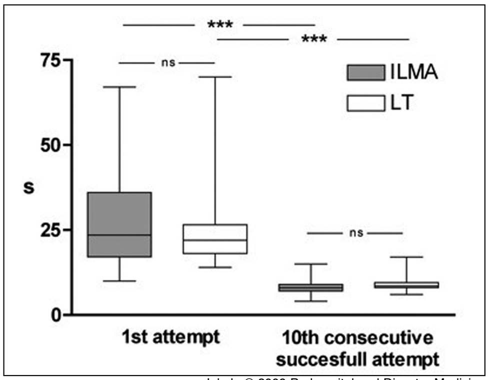




**Figure 3**—The duration of the first insertion attempt and the last insertion of a series of ten consecutive successful attempts using intubating laryngeal mask (ILMA) or laryngeal tube (LT)

(66%) insertions in the LT group and in 115 (42.6%) insertions in the ILMA group. A comparison of the times of the first and last insertion in the series of 10 consecutive successful insertions in both groups is shown in Figure 3.

The mean intuitive VAS score for the presumed difficulty of use, after seeing the video clip was 5.1 cm (range 0–10 cm) for the LT and 5.0 cm (range 0–10 cm) for the ILMA. The corresponding median values were 5.0 cm and 5.0 cm, respectively ($p$ = 0.873). The mean value of the VAS score for the perceived difficulty of use after personal hands-on experience and completion of the required 10 consecutive successful insertions, was 0.8 cm (range 0–4.7 cm) in the LT-group and 0.45 cm (range 0–2.5 cm) in the ILMA-group. The respective median values were 3.0 and 2.5 cm ($p$ = 0.466). Two subjects in the LT group and one in the ILMA-group failed to remit both their VAS scores.

**Discussion**

The present study is part of a continuous project aimed at gathering new information, experiences, and practical examples that can be adopted and applied to updating and improving the methods and practices employed in the education and training of the non-commissioned medical officers in the FDF.

The Laerdal Resusci Anne Simulator employed in the present study has previously been used in various manikin trials.[8,11,12] The use of a manikin in the primary evaluation and comparison of different devices and instruments for airway management is recommended by the authors. First and foremost, a manikin is not subject to individual variations that human beings are, and no harm can be done to a manikin. Thus, the factors determining the ease or difficulty of insertion and the basis for evaluation of the insertion technique remain identical and unaltered for all test subjects and depend mainly on the instrument to be inserted and the manual skills of the subjects. The use of the manikin also allowed for the measurement of the tidal volumes and recognition of gastric inflation, when peak insufflation pressure exceeded 150 mmHg $H_2O$.[11]

Rarely used skills are known to deteriorate, and during an airway emergency, there is no time to seek help when there is a great distance to the nearest hospital or doctor. Using a video clip to show a safe and easy way of rapidly securing the airway is a method that can be viewed on a regular mobile telephone that nearly everybody already carries with them. When there is less time to teach, new methods of teaching must to be sought.

In a previous study by Kurola *et al*, the number of insertion attempts and insertion times of 32 inexperienced paramedical students were recorded for the LT and the ILMA, as well as the CobraPLA (COB; Engineered Medical Systems, Indianapolis, IN), in a series of consenting patients (ASA I-II).[12] On first attempt the ILMA was inserted successfully by 75%, the LT by 44% and the COB by 22% of the students. However, in the present study, the LT was inserted on first attempt by 96.7% and the ILMA by 74.1% of the trainees. In addition, the mean insertion time for the first of the 10 consecutive successful insertions was shorter with the LT than the ILMA (22.0 and 23.9 seconds) compared to the respective 24.9 and 22.9 seconds in the study by Kurola *et al*.

Komatsu *et al* compared the insertion of the LT and the ILMA in a series of patients whose necks were stabilized with manual, in-line traction, and found that the insertion of the ILMA was quicker and easier than the insertion of the LT.[13] In their crossover study, the mean time required for the LT insertion was longer than for the ILMA (28 seconds; range 23–35 versus 20 seconds; range 15–25. These results support the present study in which insertion times were ≤10 seconds in 34% of the insertions in the LT-group and in 57.4% in the ILMA group. The paramedic students participating in the study by Kurola *et al*, rated the ILMA as the best device and considered it to be the most useful one when compared to the LT and the COB.[12] Initial insertion success rate was higher with the LT in the current trial. The mean VAS scores for the ILMA for the perceived ease of use given by trainees after completion of the required 10 consecutive successful insertions (0.82 for the LT and 0.45 for the ILMA) show that supraglottic devices are well-accepted by inexperienced personnel.

The LT and the ILMA are devices that can be used as alternatives for endotracheal intubation and mask ventilation. Clinical studies during real emergencies are warranted to better evaluate the LT and ILMA as alternatives to ensure the airway safely.

In peacetime, the main beneficiary of the education and training in first aid and basic life support skills received by the conscripts during their service in the FDF's Medical Corps is the civilian sector. Annually, some 260 non-commissioned medical officers complete their service and on returning to civilian life, they receive a diploma certifying this ability.

## Conclusions

No absolute superiority of the LT or the ILMA could be demonstrated with respect to their applicability for emergency airway management. Hence, both the LT and ILMA provide important alternatives to the endotracheal tube for non-professional, emergency medical personnel.

Short video clips can be valuable educational and instructional tools as demonstrated in the present study. Video clips possess several significant advantages, including, among others, repeatability, slow motion viewing, or still-pictures, and the possibility of using them for self-teaching.

These results strongly support the incorporation of the method in the training of advanced life supporting skills to the non-commissioned medical officers in the FDF's Medical School. This method even could be applied to other non-professional life support training programs.

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II



# A comparison study of using a mobile medical information system



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**Abstract**

**Purpose** – The purpose of this paper is to present the results of a comparison study of using a mobile medical information system between civilian medical students and physicians undergoing military service in Finland. Special emphasis is on differences in system usage, and perceptions towards the mobile medical system. Other points of interest are the important features of the mobile medical system, advantages and disadvantages of using the system in actual emergency situations and use of the device to search for general information.

**Design/methodology/approach** – The study is conducted between two groups of users, medical students and physicians undertaking military service.

**Findings** – The two groups are found to have similar behaviors toward the mobile system in different contexts. This study helps develop an understanding of how the two groups of users use a mobile medical information system while also providing insights of some behavioral differences between them. Not all of the differences are significant; indicating the possibility of developing a universal tool for both military and civilian contexts, but more contents of military medicine should be supplemented for military physicians.

**Originality/value** – This paper addresses an area of increasing research interest, i.e. mobile medical informatics.

**Keywords** Medical information systems, Mobile communication systems, Armed forces, Students, Doctors, Finland

**Paper type** Research paper

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## Introduction

Mobile technology has offered new freedom and potential to address many of the healthcare challenges and demands of the twenty-first century (Goldberg and Wickramasinghe, 2003).

Wireless, handheld devices and systems have started to change the ways of medical practice. A study of 2,800 medical professionals reported that mobile technology such as personal digital assistants (PDAs), smart phones and related medical decision support tools help doctors deliver better medical care (Cellular News, 2009). In 2005, Lu *et al.* carried out a review of handheld computer adoption in healthcare that discusses PDA adoption in healthcare. The PDA adoption rate for physicians is approximately 40 percent in the USA and Canada, and even more North American nurses are using them. The major barriers that limited the adoption included usability, security concerns and lack of support (Lu *et al.*, 2005). As well as actual practitioners, medical students have found use for these new technologies and are using them in increasing numbers. In the USA, approximately 60 to 70 percent of medical students and residents use PDAs for educational purposes or patient care. The most popular uses include electronic textbooks, medication reference databases and medical calculators, although patient-tracking software is also common. While most medical trainees who use handhelds appear comfortable and generally satisfied with them, certain barriers still exist, such as lack of technical experience, a preference for pen and paper, difficulty handling the small device, and concerns about data loss and security (McKeown *et al.*, 2006). It appears that initial training and ongoing technical support will be important to increase handheld computer use and maximize its potential in medical education, particularly for physicians who lack familiarity with the devices (Kho *et al.*, 2006). Mobile access to information does nevertheless possess significant potential for learning when detached from the traditional information sources and libraries (Walton *et al.*, 2005). Grasso *et al.* (2006) found in their study of medical students a significant difference between the current role of handheld computers and future expectations. The lack of institutional support was seen as a key limitation to the adoption of this technology. Arnold *et al.* (2004) discuss the future role of information technology for information sharing in disaster response. Four levels of challenges are identified: human, application, communication and security. The work presented in this paper mainly addresses the human level. Arnold *et al.* define *user friendly* as being the most important factor at the human challenge level. The importance of usability is supported in the interview with the medics where all suggestions are related to usability.

Militaries in the world are also turning to mobile technology in an effort to improve military medical practice at the point of need and at the point of care (Han *et al.*, 2007a, b). The US military is at the forefront of the development and implementation of various kinds of mobile system for its medical personnel around the world (military-medical-technology.com; MC4.army.mil, 2009). Small militaries such as the Finnish Defence Forces and other European militaries (Walderhaug *et al.*, 2008) have started to adopt commercial research and development (R&D) and off-the-shelf technology (COTS) in order to reduce costs and better integrate available mobile technology and services into military medical practice.

In this paper, we present the results of a comparison study of using a mobile medical system between civilian medical students in civilian situations and military physicians in simulated military situations. The main focus is on differences between the two groups of users in usage, behavior or perceptions toward the mobile medical information system, which is designed and implemented for civilian medicine. We report their differences on the important features of the mobile system, advantages and disadvantages of using the system in actual emergency situations and the use of the devices to search for general information.

**Research background**

The medical curriculum in Finland awards the degree of Licentiate of medicine and lasts six years. All participants of the civilian group of this study were sixth year students. Of the military physicians, most had just finished their studies; hence the education level of the two groups was very similar.

*Physicians undertaking compulsory military services*

Recruits in the Medical Reserve Officer School, located in Lahti, southern Finland, are physicians, veterinarians, dentists, pharmacists or students of these disciplines with right to practice. Training is part of the compulsory military service in Finland and is arranged annually. Each course has duration of 14 weeks.

The objectives of training are to provide the Finnish Defence Forces with medical officers who are able to:

- Lead and manage company and battalion-level emergency medical care.
- Manage typical war trauma, along with NBC medicine, in field conditions.
- Manage typical diseases that occur in field conditions.
- Manage the evacuation of wounded personnel.
- Manage field hygiene and know the basic principles of food and water hygiene, as well as recognizing food poisoning epidemics and their prevention in the field.
- Know realistic distances and evacuation times between different care locations.
- Know the international conventions regarding military medical personnel (www.mil.fi, 2009).

The training takes forms of classroom education as well as field exercises. The recruits also receive leadership and military training.

*A mobile medical information system*

A mobile medical information system was developed by the Finnish Medical Society, Duodecim, in 2002. It is a set of medical information and knowledge databases which support physicians' medical practice by retrieving knowledge and information when needed. It contains the Evidence Based Medicine Guidelines with Cochrane abstracts, the pharmacology dataset-Pharmaca Fennica with wireless update service for a complete drug (medicine) price list in Finland, the International Statistical Classification of Diseases and Related Health Problems (ICD-10) in Finnish, the Emergency Guide issued by Meilahti Hospital, a medical dictionary of over 57,000 terms and a comprehensive database of related addresses and contact information relevant to healthcare (pharmacies, hospitals, healthcare, etc.). The system also includes a drug interaction database originally developed by the Karolinska Institute, Sweden. The system is built on an XML database and can be easily modified to work with most mobile devices, with different operating systems for example: Symbian, Palm OS and Windows CE. In Finland, the device most commonly used as a platform is the Nokia Communicator 9210, 9310 or 9500. Currently, updates are delivered on memory cards. However, in the near future the system will be able to update itself partly, or completely, through the wireless network. The system is designed for and used by civilian physicians (Han, 2005; Harkke, 2006).

**Study design**

The focus of the investigation was the differences in behavior and perceptions of the usage of mobile systems between sixth-year medical students and military physicians. Both groups of participants were near graduation or had graduated, as Licenciates of Medicine. There were three reasons why we conducted the comparison study. Firstly, civilian and military medical environments differ greatly from each other. Medical students work in the civilian environment, for example in universities or hospitals, whilst military physicians practice in field exercises and in garrison. Therefore we can state that military physicians meet challenges from the harsh natural environment in which they use the medical information system. Secondly, military physicians are quite mobile in their practice and have limited access to medical information recourses by other means, such as medical books or the internet. The mobile medical information system provides them a handy access to the medical knowledge. Thirdly, military medicine differs to civilian medicine in many respects. Our aim was to study if there are needs for updating the system with more content for military medicine, and whether there was a need for new design requirements in order for the system to be used efficiently in the military context.

The project was carried out from autumn 2005 to autumn 2006 and was a co-operation between the Centre for Military Medicine, Finnish Defence Forces and the Institute for Advanced Management Systems Research (IAMSR) at Abo Akademi University and the Turku Centre for Computer Science.

The questionnaire used in this paper for assessing the usage of the system is based on a questionnaire validated in a study concerning c. 800 physicians working in the healthcare sector in Finland (Han, 2005). Some of the redundant questions concerning professional practice were omitted for obvious reasons. The questionnaire was handed to the sixth-year medical students at the University of Oulu and was completed on 26 October 2005 after using the mobile system for approximately three months. The corresponding dates for the military physicians in service were Phase I on 10 October 2005 during a field exercise and phase II on 19 December 2005 during normal conscript based military service in the Lahti garrison.

Analysis of the two groups was done by comparing behavioral differences regarding:

(1) previous training of using any mobile technologies in the past year (question 1: scale 1-4, from never, 1-2 times, 3-4 times, to 5 times or more);

(2) the important features of the mobile system for physicians (questions 2-4: "easy to use", information for medical work, information for specialties; scale 1-4, from "very important" to "not important");

(3) the barriers for the implementation of the mobile system (questions 5-7: physicians have no communicators, physicians have no time to learn to use it, it is not useful for physicians work; scale 1-5, from "fully agree" to "fully disagree");

(4) the usefulness of the mobile system (question 8; scale 4-10, from very useless to very useful);

(5) the benefits of using the mobile system (questions 9-11: finish the task fast, increases finding more accurate diagnosis and make my work/study easier; scale 1-5, from fully agree to fully disagree);

(6) using the mobile system in actual emergency situations (questions 12-15: useful, fast, effective and easier; scale 4-10, from the lowest degree to the highest degree); and

(7) medical information from the mobile system was examined, most frequently (questions 16-19: at home, at clinic, at homecare and at rounds; answer: yes/no).

In total, we investigated 19 questions with seven different perspectives. Different ordinal and nominal scales were used in order to increase the objectivity of the questions.

## Data analysis

From the two groups, 27 military physicians answered the Phase 1 questionnaire, and 28 responded to the Phase 2 survey. Of the military physicians, 27 males and one female participated in the study. Of the 30 medical students, seven males and 23 females participated. In general, these two groups were young, the age ranging from 22 to 32; with a median age of 25.

Let $r_{ij}^{(1)}$ and $r_{ij}^{(2)}$ denote the scores that military physician $i$ rated question $j$ in Phase 1 and Phase 2, respectively. Furthermore, let $r_{ij}^{(0)}$ be the answer of medical student $i$ on question $j$. Thus, for any question $j = 1, 2, \ldots, 19$ we have the following sets of evaluation scores: $\{r_{ij}^{(1)}: i = 1, 2, \ldots, 27\}$, $\{r_{ij}^{(2)}: i = 1, 2, \ldots, 28\}$ and $\{r_{ij}^{(0)}: i = 1, 2, \ldots, 30\}$.

### *Computing the average value of a representative user*

In order to manipulate the answers, for all $k = 0, 1, 2$ we need to represent $r_{ij}^{(k)}$ on a numerical scale. Originally, we received answers as quantities on ordinal and nominal scales. We then did the following:

(1) For questions 1-15 focusing on perspectives 1-6, we assigned values to the ordinal scale such that they preserve their rank on the numerical scale.

(2) For questions 16-19 associated with perspective 7, we assigned yes answers with 1 and no answers with 0. In cases of missing data, an average value of 0.5 was assigned.

Now, by using elementary arithmetic calculations we computed the average score of the groups associated with both the medical students and military physicians in Phase 1 and Phase 2.

Considering the answers of military physicians, the average score was computed as follows:

$$p_j = w_1 \times \frac{1}{27}\sum_{i=1}^{27} r_{ij}^{(1)} + w_2 \times \frac{1}{28}\sum_{i=1}^{28} r_{ij}^{(2)},$$

where weights $w_1 = 3/14$ and $w_2 = 11/14$ represent the degree of applicability of the replies to question $j$ in the environment of Phase 1 and Phase 2, respectively, in the overall evaluation. The military physicians had 14 weeks of training, three of which were in field conditions and 11 in the garrison. We note that the first and second term in the formula above includes the pure arithmetic average of the scores that military physicians answered to question $j$ associated with their training in Phase 1 and Phase 2, respectively. Furthermore, since $w_1 + w_2 = 1$ and $w_1, w_2 \geq 0$, $p_j$ actually computes the weighted average of the average Phase-dependent answers.

With the answers of medical students, we computed the average answer to question $j$ by the following formula:

$$s_j = \frac{1}{30}\sum_{i=1}^{30} r_{ij}.$$

That is, $s_j$ computes the simple arithmetic average of all individual answers to question $j$.

*Computing the relative difference*

In the final step, we computed the relative difference between the answers we received from military physicians and medical students. Let us consider question $j$ of the survey, when $j = 1, 2, \ldots, 19$. Minimum and maximum values from the scale of possible answers were denoted by $m_j$ and $M_j$, respectively. For instance, $m_j = 0$ and $M_j = 1$ for questions $j = 16, 17, 18, 19$. We defined width of the scale or degree of freedom of choice by $d_j = M_j - m_j$ for $j = 1, 2, \ldots, 19$. Then, we computed the relative difference between the answers by using the following formula:

$$q_j = \frac{|p_j - s_j|}{d_j} = \frac{|p_j - s_j|}{M_j - m_j}.$$

## Results

This paper set out to study the behavioral differences between two groups of users, medical students and military physicians, concerning their usage of the mobile system.

Figure 1 shows the comparison results. The left $Y$-axis indicates the numerical scale we adopted in the analysis. The right $Y$-axis was the percentage we used to show the relative difference between the two groups. The significance level was set at 0.05, which was 5 percent.

Results in Figure 1 show that for most of the questions we analyzed, both groups had similar behavioral perceptions toward the mobile system; the relative differences were mostly below the 5 percent significance level, with very few exceptions.

Since the survey for the medical students was implemented after use of the mobile system for approximately three months, it is not surprising to find out that they received slightly more training on the usage of mobile technology in the past year than the military physicians. The relative difference was above 5 percent.

The two groups of users shared fairly similar perceptions on the important features of the mobile system with relative differences below 5 percent. Ease of use, information for medical work and information for specialties were all considered as important, the average scores were below 3, ease of use being one of the most important features of the mobile system.

The mobile system being useless and having no time to learn its usage were not regarded as barriers for implementing the system for the target study groups. Comparatively, not owning a Nokia 9210 communicator, the mobile platform for running the system, was pointed out as a barrier with the average score slightly below 2. The possible reason is that a communicator is a relatively expensive device for the groups to buy in order to use the mobile system. In general, the two groups showed the same view of what were the barriers for implementing the mobile system.

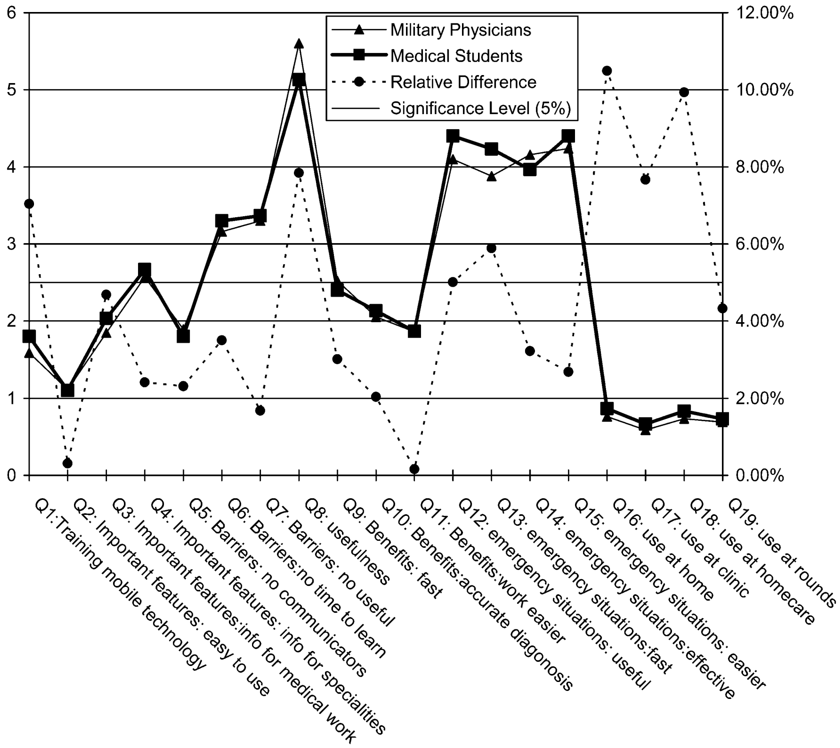


**Figure 1.**
Behavioral differences between the two groups

Both groups have indicated that the mobile system was useful with the average scores above 5. The military physicians ranked it a bit higher. The relative difference between the two groups is above 5 percent, hence slightly significant. The difference was most likely due to the military physicians' lack of access to other databases when working in the field or in the garrison. Thus, the mobile system gave an alternative for them to access medical knowledge and information under these unique circumstances.

Both two groups agreed that by using the mobile system their work was made easier and was listed as the most important advantage with the average score below 2 (agree-fully agree). The two other advantages; by using the mobile system work would be made faster and would provide accurate diagnosis, achieved a score of 2-3 (agree-neutral). In general, the results have shown that the mobile system brought some degree of benefit for the group's work either in the campus or in simulated military environments. The relative differences between the groups were very marginal, below the significance level 5 percent.

The two groups believed that use of the mobile system in emergency situations may not be useful, or make work faster, more effective or easier with average scores from 4-5 (4 being the lowest degree). Scores from the medical students were slightly more positive than those of military physicians, especially when asked if the mobile system would make their work effective in emergency situations. The slight difference may be due to the fact that the emergency situations are different with more serious injuries in the military context compared to those found in the civilian environment. Military physicians have to react quickly, mostly, in severe field conditions. This means that only the knowledge the physician has learned by the heart can be used; other information systems are of little use in such acute situations.

The two groups liked to use the mobile devices for searching medical information in many environments but seemed to behave differently when use occurred during ward rounds, in the clinic or at homecare, with the relative differences above 5 percent. Using the system as much as possible can improve the physicians learning capability and enhance their knowledge in many different occasions. The relative differences between the two groups can be explained by the fact that military physicians have to acquire new knowledge of military medicine, being in nature more urgent and important during the training. As the system is developed for civilian medicine, the military physician's searches or inquires may not find results in the medical system. Medical students, however, may not encounter such problems.

## Conclusions

This study has helped develop an understanding of how the two groups of users use a mobile medical information system while also providing some insights of some behavioral differences between them. Due the complexity of the study design, the aggregation algorithm we have adopted in this paper helped us to compute the representative users from the two groups, making the analysis clear and easily understood.

As the study encased both a civilian university campus and a military environment, the results here give evidence that there appears to be a general need for this type of mobile system to be developed further. The different environments where medical practice took place seemed not to be a crucial factor in having an impact on the two groups of users' behavior. The implications of this result for the developers of such systems are twofold: Firstly, it seems to be possible to develop universal tools that can be used in a wide range of contexts, although the contents of the system should be updated and supplemented to suit the needs of military medicine. Secondly, the characteristics of the system itself are crucial for the usage and effects of such a system. The differences between the two groups have given some insights for improving the system in order to be suitable for military purposes, for example to increase its usefulness in emergency situations and use in different conditions.

This study is based in only one country. Despite the contextual difference between our two groups, both groups are a subset of medical students. We used a small sample of civilian medical students and medical students undergoing military service. In the future, we aim to conduct our research in the real military field situation. Despite these limitations, the study suggests that handheld computers are an important and evolving part of the both two groups' resources in medical education. Incorporating handhelds in medical training provides valuable access to point-of-care information that may positively impact learning and patient care.

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III

# Implementing RFID technology in a novel triage system during a simulated mass casualty situation

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**Abstract:** The purpose of this study is to determine the applicability of Radio Frequency Identification (RFID) technology and commercial cellular networks to provide an online triage system for handling mass casualty situations. This was tested by a using a pilot system for a simulated mass casualty situation during a military field exercise. The system proved to be usable. Compared to the currently used system, it also dramatically improves the general view of mass casualty situations and enhances medical emergency readiness in a military medical setting. The system can also be adapted without any difficulties by the civilian sector for the management of mass casualty disasters.

**Keywords:** e-healthcare; triage; Radio Frequency Identification; RFID; field medicine; disaster management; simulated mass casualty situation; mobile phone.

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Vice President and General Manager prior to purchasing the company in 1989. He is also a highly decorated Medical Service Corps Reserve Warrant Officer and is currently responsible for the development and testing of new medical equipment and emerging technologies for the Finnish Defence Forces. Additionally, he plays a major role in the Finnish Defence Forces' development of techniques, procedures and logistical integration for procured medical equipment.

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## 1 Introduction

Triage is a process used by medical personnel, defined as the sorting out and classifying of casualties according to the need and urgency for acute medical care and it can take place anywhere along the line of evacuation, from the point of injury to the hospital, where definitive treatment is given (Dufour *et al.*, 1988). Triage has also been called the keystone of the management of mass casualty situations and has shown to be the most important determinant in combat casualty care (Auf Der Heide, 1989; Swan and Swan, 1996).

The North Atlantic Treaty Organization forces, as well as many civilian systems, classify casualties into four categories based on the need and urgency for medical care:

1 immediate (cannot wait)

2 delayed (has to wait)

3 minimal (can wait)

4 expectant (dead or dying) (Bowen and Bellamy, 1988; Bowen, 2004).

The classification of the casualties according to their need for medical care and to ration the limited medical resources aims at doing the greatest good for the greatest number of casualties.

Triage classification is frequently a complex task requiring the precise yet rapid assessment of the patient, as well as sufficient medical knowledge of potential pathophysiology. Triage in the field also requires the quick and distinctive marking of the casualties according to their triage category. The priorisation of the casualties according to their categories ordains their order for both treatment and evacuation (Greaves *et al*., 2001; San Pedro *et al*., 2004; San Pedro *et al*., 2005).

The term ‘situational awareness’ means the comprehension of situation-specific factors that affect performance in complex tasks and it renders possible the making of real-time effective decisions during rapidly evolving events (Fry and Lenert, 2005). It is of great importance particularly in the medical response to major incidents, in which the effective use of limited resources has direct implications on the care and survival of the casualties.

The Field Medical Services (FMS) of the Finnish Defence Forces comprise a chain of medical facilities providing different levels of medical care from the frontline to the evacuation hospitals. The major difficulty in commanding the FMS has been the lack of sufficient and timely information from the field. During mass casualty exercises, the relevant information, including among others the location of the casualties, their number and triage categorisation, reaches the command centre with delays of up to 24 h.

This study introduces the application of a newly standardised technology called Near Field Communication (NFC) for the handling of triage information. The system is based on standard commercial mobile phone networks and Radio Frequency Identification (RFID) tags.

RFID is a system where electronic tags containing information can be read and written on remotely with no need for line of sight. The technology is in wide use in different logistics operations and industrial/commercial enterprises. Within the field of healthcare, the technology has been used for tracking equipment and supplies. Some systems have been implemented for patient and equipment identification in hospital environments (Hosaka, 2004; Wang *et al*., 2006; Davis, 2004).

Our tested system allows for:

- marking the patients
- communicating triage information and previous medical records to the receiving medical facilities
- communicating triage information to the incident/medical command centre.

The new system is expected to provide the command centre and the next receiving medical facilities a previously unattainable real-time overall account of the true situation in the field. The system was tested during a military training exercise known as Pyry 2006.

A software system, known as the Nokia Service Manager (SM), was used to authenticate the phone users, to manage tags and the allowed Global System for Mobile Communications (GSM) phones and to map the soldiers’ personal data into the individual tag identities received from the field. The received identity and related data from the SM was then sent over a secure encrypted connection to the external IT system for further analysis (Nokia, 2007). It was possible to have real-time visibility of the incident by analysing the individual data events.

The authors are not aware of any previous deployments of RFID-based triage solutions where a standard mobile phone had been used as the RFID reader/writer or utilising Short Message Service (SMS) messages as a carrier for the triage information to the next receiving medical facility and central medical command.

III

## 2 Methods

### *2.1 Technology*

The triage system evaluated in the present study utilises commercially available low-cost components, including RFID and mobile phone technology consisting of the following components: the RFID tags, a mobile phone (Nokia 5140i) equipped with an integrated RFID reader/writer, the 'mTriage' software application (WM-Data, Logica CMG Co., Finland) and the Nokia SM computer server with a connection to the external IT system that comprises a 'Merlot Medi' server and software application.

The Nokia 5140i has an approximate battery life of 225 h on standby and about 3.5 h of talk time. In terms of power consumption, the use of mTriage falls somewhere between these two figures, most likely closer to the talk time than the standby time. In the Pyry 2006 field trial, the batteries seemed to last well for a few days in subzero conditions.

**Figure 1** The triage category data entry screen in the Nokia 5140i mobile phone

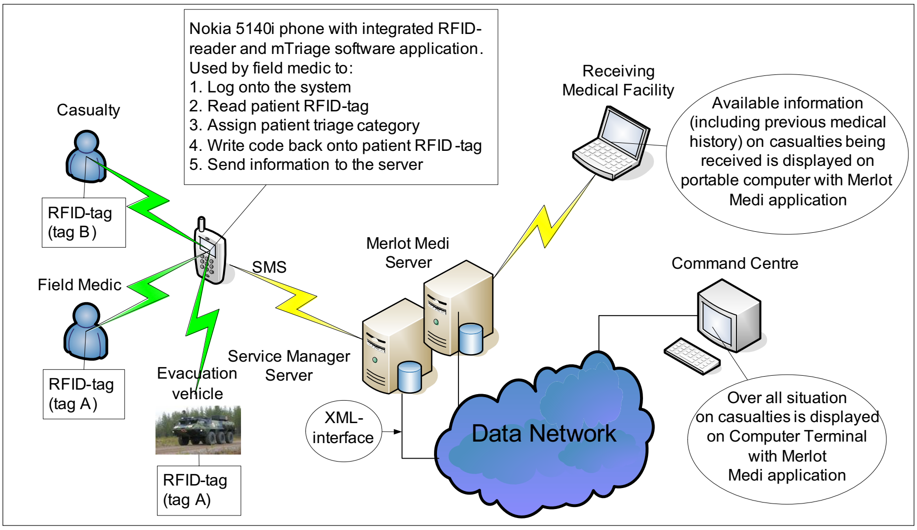

In this study, only passive (ISO 14443A) RFID tags with 1 KB of RAM memory were used. As the reader provides electromagnetic energy that activates the tag within the reading range of 0–10 cm, no internal power source (*e.g.*, battery) is needed in the tag. A commercial civilian GSM network (TeliaSonera PLCo, Finland) was utilised to communicate with the server (back end system) (Harkins and Reigelsperger, 2005; Borriello, 2005). This technology is not dependent on GSM or any other network technology as, for example, TErrestrial Trunked Radio (TETRA) competence devices are conceivable.

The mTriage software application allows the assignment of each patient to one of the four triage categories (Bowen and Bellamy, 1988; Bowen, 2004). Once a patient is assigned to a triage category, the program automatically sends a message to the Nokia

SM (back end system) by storing it on his/her personal RFID tag. The server then forwards the data as an advance warning to the next receiving medical facility, as well as to the command centre.

The Nokia SM, with specially developed software, was used to authenticate the users of the mTriage application, *i.e.*, the creator (medics) of the current triage, and to log all RFID tag reading events. It also enabled the casualties' personal medical data to be matched by the Merlot Medi server with the individual tag identities received from the field. The matched information on the patient was then forwarded over a secure encrypted connection to the computers within the medical facilities and the command centre (Figure 2). The Merlot Medi end user interfaces installed on the computers displayed the current number of casualties expected to be evacuated to the specific facilities, as well as the casualties' triage categories and previous medical data (Nokia, 2006).

**Figure 2** The technical flow of data between the triage system components (see online version for colours)




The mTriage and Merlot Medi-based solution offers several clear advantages over the manual legacy routines. The most important is, undoubtedly, the real-time information on the casualties. This is the primary information used to determine the combat capability of the troops, as well as the load on the medical facilities and evacuation chains. Based on this information, the medical resources and the wounded can be optimally allocated. Not far behind comes the access to this information. When the information on the medical/evacuation situation is distributed towards the frontline (via mobile devices), the medical personnel *in situ* can better estimate the near-future patient load up the evacuation chain and, thus, dynamically distribute the patient destinations to avoid congestion in the receiving medical facilities.

### *2.2 Test settings*

The system was tested by the Finnish Defence Forces Centre for Military Medicine during a large military field exercise (Pyry 2006) involving 4000 conscripts and 800 motor vehicles and realised in the harsh subarctic conditions of Central Finland in December 2006.

Of the 45 field medics participating in the exercise, 18 were given a personal RFID tag, referred to as Tag A. They also received an RFID reader-enabled Nokia 5140i mobile phone. Similar equipment was provided to seven medical facilities and five evacuation vehicles, with location-specific tags marked tagC. All field medics using the new triage system received a 10 min instruction session on using the system.

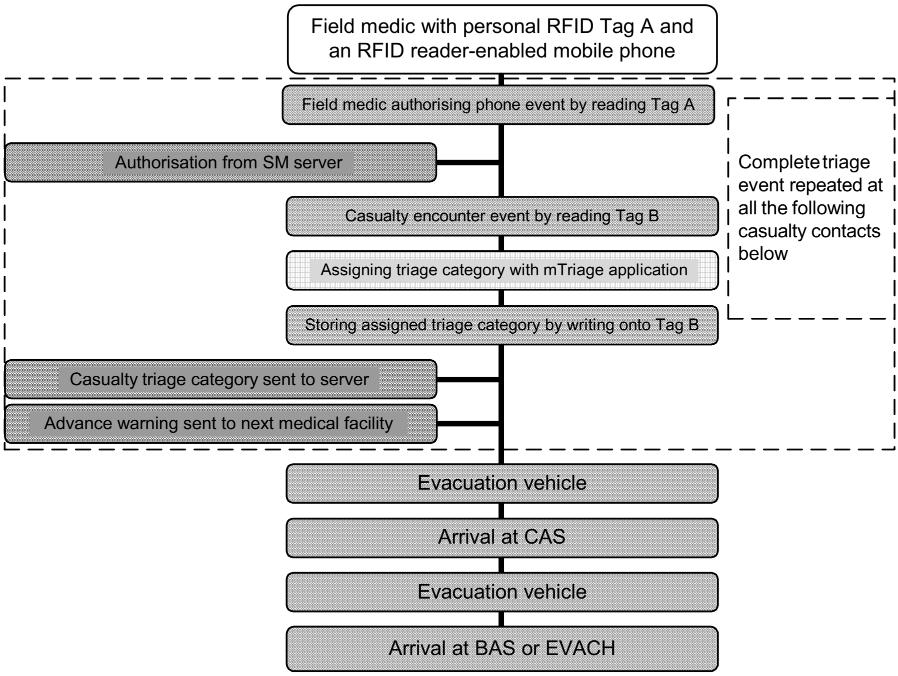
The 130 conscripts participating in the study were randomly selected as mock casualties for the study. These conscripts were informed that they had been injured and an injury card describing each individual's mock injury profile was hung around their necks. An RFID tag, referred to as Tag B (representing a normal soldier's 'dog tag'), was attached to their injury cards. The triaging of the mock casualties was based on the injury profile on their injury cards.

### *2.3 The triage workflow*

The triage workflow begins with the field medic reading his own RFID tag (Tag A) by touching it with the mobile phone. This turns on the mTriage application, authenticates the identity of the medic and allows the application and the phone to be used for triage. The medic then touches the casualty's injury card (Tag B) with the phone and assigns a triage category for the victim, using the mTriage application according to the given injury profile. Next, the medic touches the casualty's Tag B once more with the phone and saves the wounded soldier's triage category into the RFID memory. The triage category is then automatically sent by SMS via GSM network as an advance notice to the medical facility receiving the patient. The information on Tag B can be assessed with readers, even if the GSM network and back end systems would totally fail. After first aid, the casualty is evacuated to the Company Aid Station (CAS), where the receiving medic can repeat all the same steps as the medic who sent the casualty's data. By reading the casualty's Tag B, the medic can retrieve and update the casualty's previous triage category when necessary.

A second advance warning is then sent via the Nokia SM to the next medical facility, *e.g.*, the Battalion Aid Station (BAS) or the Evacuation Hospital (EVACH). This process is repeated in the following medical facilities and in the evacuation vehicles along the evacuation chain (Figure 3).

**Figure 3** The flow diagram of the triage process in the triage system evaluated in the present study




Notes: White: the first point of contact for the casualty with the FMS.

35%: automatic data transfers via SMS.

25%: RFID tag reading/writing events.

10%: software data input selecting one of four triage categories.

CAS: Company Aid Station.

BAS: Battalion Aid Station.

EVACH: Evacuation Hospital.

🗎 first point of contact with casualty, 🗎 automatic data transfer via SMS, 🗎 RFID tag reading/writing, 🗎 software data input and selecting triage category.

## *2.4 Collection of data*

The field medics' ease of use and confidence in using the RFID reader-enabled mobile phone with the mTriage software application was assessed with two 10 cm Visual Analogue Scales (VAS), one before the personal experience (VAS 1) and one after the personal experience (VAS 2).

After having attended the 10 min instruction session and prior to any actual personal and hands-on experience, the medics were requested to express their belief and personal confidence in the ease of using the triage system on the VAS, with 0 depicting 'I believe I can use the system' and 10 for 'I believe I cannot use the system' (VAS 1). Following personal experience and after two consecutive successfully performed triages, the participants expressed their experienced difficulty of using the system on the VAS, with 0 depicting 'Using the system was very easy' and 10 for 'Using the system was very difficult' (VAS 2).

The usability of the new triage system was evaluated with a standard post-test questionnaire, with eight sections containing a total of 27 questions regarding the field medics' subjective confidence in the personal use, general use and applicability of the system (Table 1). Free comments were allowed to be made at the end of the questionnaire. Of the 45 field medics, 14 were randomly selected and requested to answer the questionnaire. The technological suitability of the system for field use was measured by analysing the recorded data transfers, tag events and the number of failed data operations.

**Table 1** The eight-point opinion survey questionnaire with responses to the presented 27 questions

| *Question* | *Agree (n)* | *%* | *Disagree (n)* | *%* | *No opinion* |
|---|---|---|---|---|---|
| 1 *RFID tag reading* | | | | | |
| Difficult | 0 | 0.0 | 12 | 100.0 | – |
| Time-consuming | 3 | 25.0 | 9 | 75.0 | – |
| Mostly successful | 12 | 100.0 | 0 | 0.0 | – |
| 2 *RFID reader operation* | | | | | |
| Mostly nonproblematic | 12 | 100.0 | 0 | 0.0 | – |
| Difficult | 0 | 0.0 | 12 | 100.0 | – |
| Reliable | 11 | 91.7 | 1 | 8.3 | – |
| Technical deficiencies | 3 | 33.3 | 6 | 50.0 | 3 |
| 3 *Application of mTriage software* | | | | | |
| Easy to use | 12 | 100.0 | 0 | 0.0 | – |
| Reliable | 11 | 91.7 | 0 | 8.3 | 1 |
| Deficient | 1 | 9.1 | 10 | 90.9 | 1 |
| Good compatibility | 11 | 100.0 | 0 | 0.0 | 1 |
| 4 *RFID patient triage* | | | | | |
| More time-consuming than normal patients | 7 | 63.6 | 4 | 36.4 | 1 |
| Delayed by technology | 4 | 36.4 | 7 | 63.6 | 1 |
| Swift and reliable | 9 | 81.8 | 2 | 18.2 | 1 |
| 5 *RFID versus normal patients* | | | | | |
| RFID and normal patients are dissimilar | 2 | 16.7 | 10 | 83.3 | – |
| RFID patient triage was arduous | 0 | 0.0 | 11 | 100.0 | 1 |
| Normal patient triage was more arduous | 4 | 40.0 | 6 | 60.0 | 2 |

**Table 1** The eight-point opinion survey questionnaire with responses to the presented 27 questions (continued)

| *Question* | *Agree (n)* | *%* | *Disagree (n)* | *%* | *No opinion* |
|---|---|---|---|---|---|
| 6 *Training* | | | | | |
| Sufficient for using RFID technology | 12 | 100.0 | 0 | 0.0 | – |
| Sufficient for using application | 11 | 100.0 | 0 | 0.0 | 1 |
| Assistance received while using system | 10 | 83.3 | 2 | 16.7 | – |
| Received assistance was sufficient | 12 | 100.0 | 0 | 0.0 | – |
| 7 *Technology and application* | | | | | |
| Suitable for personal use | 12 | 100.0 | 0 | 0.0 | – |
| Supports my work | 10 | 90.9 | 1 | 9.1 | 1 |
| I am ready to use the system in the future | 12 | 100.0 | 0 | 0.0 | – |
| 8 *The system* | | | | | |
| Makes my work easier | 10 | 90.9 | 1 | 9.1 | 1 |
| Increases my efficiency | 9 | 90.0 | 1 | 10.0 | 2 |
| Helps me perform my tasks quicker | 6 | 75.0 | 2 | 25.0 | 4 |

Note: The percentage (%) is the percentage of answers of 12 participants.

### 2.5 *Statistical analysis*

Statistical analysis was performed using the GraphPad Prism (version 4.0a) program for Macintosh (GraphPad Software, San Diego, California, USA). Approximately 95% Confidence Intervals (CI) were calculated using the modified Wald method. A p-value of less than 0.05 was considered significant. The Wilcoxon-matched pair-signed rank test was employed for analysing the differences between the before and after use of the system.

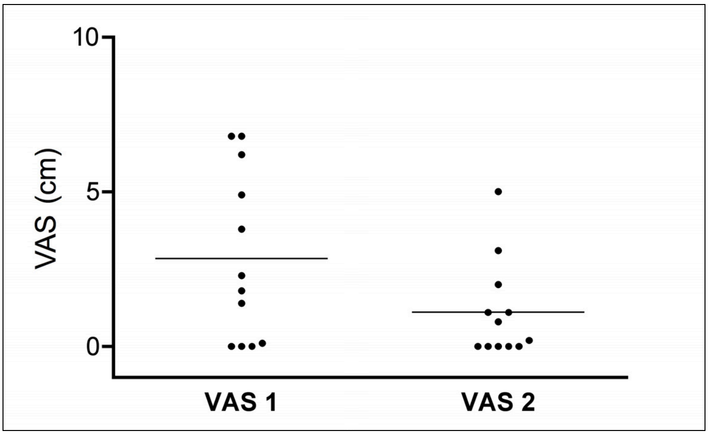
## 3 Results

Of the 14 field medics randomly selected to complete the entire questionnaire comprising 27 questions, two failed to do so and were excluded from the study. The remaining 12 field medics (ten males and two females) completed both the VAS analyses and the questionnaire. Of these 12 field medics, one was a physician, four were college graduates, five had finished high school and two had graduated from a vocational school. Their mean age was 21.8 years. All 12 had good knowledge of and experience in using a mobile phone, as all were already previously accustomed to using a Nokia mobile phone.

The mean VAS 2 score was significantly lower than the mean VAS 1 score ($p = 0.0137$, Figure 4). During the simulation exercise, a total of 579 tagging events were recorded, comprising 147 (25.4%) A Tags (identification) and 432 (74.6%) B Tags (operative). One patient was involved in 11 tagging events and this was the highest recorded number of taggings per patient. No failures occurred in tag reading or data transfers. The results of the eight-point survey questionnaire are presented in detail in Table 1.



**Figure 4** The subjective confidence of the field medics in their proficiency in using the RFID-enabled Nokia 5140i mobile phone, the mTriage application of the phone and the triage of patients




Notes: VAS 1: results prior to hands-on experience.
VAS 2: results after hands-on experience.
0 = the most positive feeling.
10 = the most negative feeling.

## 4 Discussion

The successful use and implementation of continuously evolving mobile and wireless technologies in several fields have also highlighted the opportunities of applying them in the field of healthcare and their potential importance for supporting timely access to decision-critical information (Padmanabhan *et al*., 2006).

Resource allocation in mass casualty situations is a significant logistical problem, both in military and civilian environments. In the military domain and particularly under rapidly changing martial conditions, reliable and timely situational awareness is crucial for making the correct decisions on the allocation of the available resources. Under all conditions, the use of limited and precious resources must be optimised to provide the maximum benefit to the largest possible number of casualties. In mass casualty situations involving extensive areas, only the ability to collate information on the number of patients and their triage categories in different regions of the area makes possible the most efficient and optimal use of limited rescue capacities.

Without situational awareness, the likelihood that the decisions made by the Rescue Operation Command are wrong increases and are likely to lead to the suboptimal use of available resources and the inferior care of the casualties. Situational awareness is vitally important in civilian circles in cases of accidents or disasters involving greater numbers of casualties requiring help within a limited geographical area, for instance, in bus or train accidents. Both its serviceability and significance increase notably when the number of casualties grows and larger areas are involved, for instance, in natural disasters or other catastrophic and rapidly evolving events. In the perspective of the distribution of the available resources in a mass casualty situation, the benefits of having timely information are obvious. The triage system employed in the present simulation study was found to enhance situational awareness by providing improved real-time monitoring of the casualties.

Mobile technology has already previously been suggested to be a major resource for streamlining and heightening the processes of emergency and disaster medicine (San Pedro *et al*., 2004). In this respect, a novel aspect of the present study was the successful application of emerging new mobile technology by utilising commercial off-the-shelf hardware and a public and commercial GSM network (TeliaSonera, Finland) in achieving a functional and dedicated emergency medical communication system for delivering real-time data from the field, as suggested by Lenert *et al*. (2005) and Killeen *et al*. (2006). Testing the applicability and reliability of the new system thus constituted an integral part of the aims of updating and increasing the functionality and effectiveness of the present military medical responses provided by the Field Medical Services of the Finnish Defence Forces, as well as its potential applicability for the civilian sector.

RFID is a quickly embraced, convenient and easy to use means of identification and it is also applicable to automatic operation. Moreover, it combines the advantages that are not available in other identification technologies. RFID can be supplied both as read-only or read/write chips. It does not require direct contact or line of sight in order to function and it also functions under varying environmental conditions, maintaining excellent data integrity.

As the technology is difficult to counterfeit, RFID also provides high levels of security (Intermec, 1999). The protection of the tags' privacy is achieved by the prevention of unauthorised reading and the blocking or jamming of electric waves (Ohkubo *et al*., 2005). Due to the high demands on data security, both the technology and data stored in the RFID tags must be absolutely secure. In the present study, security was guaranteed by the necessity of very close range reading of the tags, providing protection against possible electronic interference. Only a serial number was stored on the tags and the rest of the necessary data were obtained from a server.

In the present study, the SMS channel of the public GSM network was used, as it had been shown to be remarkably resistant to congestion when other voice and data channels are overwhelmed; according to a GSM operator (TeliaSonera Finland), SMS evades congestion (McAdams, 2006; Scott *et al*., 2006).

To assess the improvement in situational awareness in the command centre of the medical service, an interview of the Chief Medical Officer (CMO) was performed after the exercise. According to the post-exercise comments made by the CMO at the command centre, the tested new system provided a timely and true picture of the prevailing situations and greatly improved both the general management and planning of the whole operation. All expectations concerning the applicability of the novel NFC system and technology were surpassed by the results of this pilot study. The arguments for replacing the old system with the new system are, thus, well-founded and the new system can also be recommended to be adopted by the civilian sector for the timely and reliable transmission of data in response to and the management of multicasualty accidents and disasters.

The system presented here has clear advantages over the traditional method of using paper cards attached to the patients. A paper card is, naturally, cheap to buy, but are easily destroyed or lost. Paper cards even have classic problems such as bad handwriting and missing information. Any electronic system should be able to remedy these problems.

The novel aspect of our system, using commercial products and networks in combination with some tailored parts, is a cost-effective way to introduce new technology to the field, but the commercial parts of the system do have some drawbacks. First, the terminal device is not seriously rugged and might break easily. The compactness of the device may even be a problem – the device is easily lost. The chosen data carrier, a commercial GSM network, is naturally easily jammed or destroyed in a military crisis. In a civilian mass casualty situation, the text message gateway has proven to be one of the most robust and reliable communication networks.

The system addresses the problems in delivering situational awareness higher in the command chain. This, the system does well. However, as the RFID tag can only be read with a reader, the status of a patient is not clearly visible, as is the case with colour-coded paper cards.

The purpose of this study was to demonstrate the feasibility of a system that uses NFC and RFID technologies in the field. The field medics could use the system, the data transfers were successful and as such, the test was a success. Further development of the data systems in field medicine would naturally require connections to different data transfer networks that are less vulnerable in a military crisis. The actual data storage should also have enough redundancy in different physical locations to ensure data safety. The tagging system should have a human-readable element as well in order to simplify the work of the transport and field personnel. The findings here do provide some guidance for designing the next generations of field medicine management systems, even as further studies with alternative technologies are still needed.

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IV

# Increased situation awareness in major incidents – Radio frequency identification (RFID) technique: a promising tool

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Increased situation awareness in major incidents – Radio frequency identification (RFID) technique: a promising tool

IV


## Abstract

**Introduction** Management systems in disasters are constantly challenged to improve situational awareness in multi-casualty situations. In this study we evaluated a system that utilizes commercially available, low-cost components, including Radio Frequency Identification (RFID) and mobile phone technology.

**Methods** The feasibility and the direct benefits of the system were evaluated in two separate simulated mass-casualty situations; one in Finland involving a passenger ship accident resulting in multiple drowning/hypothermia patients and another at a major airport in Sweden with a plane crash scenario. Both simulations involved multiple agencies and functioned as a test setting for comparing the disaster management's situational awareness using the RFID-based system. Registration of triage was done by using both an RFID-based system, where the data automatically was sent to the medical command, and **also** a traditional method using paper triage tags. The situation awareness was measured directly by comparing the availability of up-to date information at different points in the care chain with both systems.

**Results** Information about the numbers and status or classification of the casualties was available over an hour earlier using the RFID system compared to the traditional method.

**Conclusions** The tested system was quick, stable, easy to use and proved to work seamlessly even in harsh field conditions. It surpassed the traditional system in all respects. It also improved the general view of mass casualty situations and enhanced medical emergency readiness in a multi-organizational medical setting.



Keywords: Disaster Management, RFID, Triage, Mobile Technology, Situational Awareness, Simulation, Mass Casualty situation, Smart Tag, National Triage Tag, Emergency medical services, EMS.

## Introduction

The initial activity of first medical responders at the scene of a major incident or disaster is to establish command and control and then proceed with the triage process (1). Triage is a method of sorting patients into categories according to priorities and available resources. The goal is to rapidly identify the most seriously injured who are in need of immediate medical measures and/or transport to a medical facility; essentially getting "the right patient to the right place at the right time". When there are a large number of casualties, triage principles emphasize "the greatest good for the greatest number" (1). Simplified triage systems have been developed to allow the rapid determination of priorities for patients, taking into account both the victim's condition and logistical realities (2-3).

Some of the triage scoring tools are based on physiological signs. The Triage Revised Trauma Score (RTS) is based on respiratory rate, systolic blood pressure and Glasgow Coma Scale (GCS) (1). According to the Major Incident Medical Management and Support (MIMMS) concept, triage revised trauma score (T-RTS) is the most suitable triage system for pre-hospital triage (1). Based on these algorithms, many emergency medical services (EMS) use paper triage tags. These tags are attached to the patient, identifying patients according to triage category in order to aid casualty processing (4). Triage categories are colour coded to aid in sorting, treatment and transport operations. Tagging at the disaster site is one measure to ensure that the most severely injured patients are the first to be transferred to the casualty collection area and to the receiving medical facility. One type of triage tag is the Smart Tag™, which also allows documentation and the change of a casualty's triage class without tag replacement (5). Upon arrival at the Emergency Department (ED) or trauma centre, EMS personnel must efficiently and accurately communicate critical information to receiving staff. This traditional turnover is based on handwritten documentation and paper triage tags.

### Communications technology

There is an ongoing development of new technical solutions to improve medical response for major incident and mass-casualty incidents. A major challenge for mass casualty situations response is communication and information management to improve situational awareness. Some studies have highlighted the outcome of real-time integrated information systems, by tracking casualties in order to perform patient care by integrating field-to-ED care workflow (6-7). In addition to this, using

RFID technology in healthcare has already been established within hospital supply chains using RFID tags in tracking and tracing medical equipment and devices (8-9). These technologies have been combined in a real-time RFID- and commercial mobile network- based mTriage® system introduced by Jokela et al**.** (2008).



The term 'situational awareness' means the comprehension of situation-specific factors that affect performance in complex tasks and makes effective real-time decisions, during rapidly evolving events, possible (10). It is of great importance particularly in the medical response to major incidents, in which the effective use of limited resources has direct implications on the care and survival of the casualties.

The Emergency Medical Services (EMS) of Finland and Sweden comprises a chain of medical facilities providing different levels of medical care from the disaster area to the hospitals. The major difficulty in commanding the EMS has been lack of sufficient and timely information from the disaster, for example, the scale of the accident and the availability of resources.

**Aim**

The purpose of this study was to increase the knowledge of the applicability of Radio Frequency Identification (RFID) **systems** and their potential to provide real-time overall situational awareness to those overseeing the medical management of the operation.

## Materials and Methods

### Technology

The tested system consists of:

- RFID -read/write capable mobile phones or TETRA -radios with Logica "mTriage" software (*Triage-phone*) distributed among the rescue personnel "in situ", including volunteers (*Triage-personnel*).
- RFID-tags attached to "zipper necklaces" (*Triage-tags*) for fast and reliable deployment on casualties

- Rugged laptop and/or tablet PCs with Logica “Merlot Medi Mobile” software (*Triage-PC*) for clerical officers at the scene or at evacuation and treatment facilities

- A centralized disaster information system; in this study, a Logica “Merlot Medi Server” (*Triage-service*)

- World Wide Web (WWW) -pages and means to access them (*Triage-web*) for the real time situation information on **casualties** and their evacuation.

The *Triage-mobile phone* is intended to be used by all medical rescue personnel, whether professional or volunteers, who are capable of performing an intuitive triage. All victims are to be tagged “in situ” with *Triage-tags* regardless of injury. The *Triage-PC*s enables the input of additional patient data such as injury, evacuation, treatment and personal information by the clerical officers on the scene or along the evacuation process. The *Triage-service* receives and distributes the triage and patient information to all necessary persons and levels of management, acting as a centralized storage point for all the information thus providing an excellent source material for accurate performance analysis. The *Triage-web* is a “read only” website for distributing the real time situation information. It can be accessed via almost any web browser on any computer or smart phone.

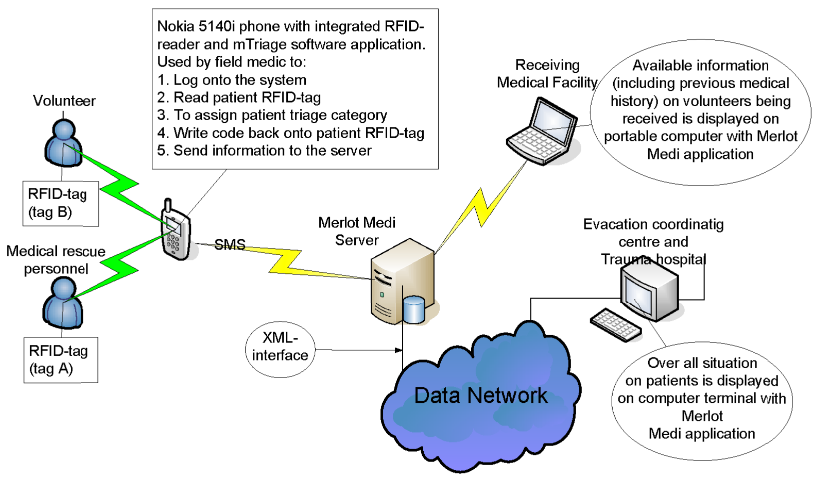


Figure 1. The technical flow of data between the triage system components

**Test setting in Finland**

The first part of the study took place at Lake Vesijärvi in Lahti, Finland, on the 27th of September 2008. The situation began as a search operation for unexploded ordnance discovered at the bottom of the lake based on gathered information. In connection with the search, a passenger ship departing from the port runs aground close to the diving site. In the aftermath of the grounding, emergency services professionals rescue both floating and injured passengers. Of the simulated patients, eight out of the total 30 passengers and crew onboard had jumped off the boat**.** Nine were classified **as** seriously injured and ten, mildly injured**;** five triage category 1 (Immediate) patients, four category 2 (Urgent) patients and 10 category 3 (Delayed/Walking Wounded) patients. Participating in the training exercises were the emergency services rescue department, in co-operation with the police, Finnish Navy, the Centre for Military Medicine, emergency response centre administration, Finnish Border Guard, the local lake rescue association, Finnish Red Cross (FRC) and World Wide Fund For Nature (WWF).



**The system process:**

Once at the disaster scene, the triage-personnel began to perform intuitive triage and triage tagging of the casualties. The triage class allocated is stored on the tag and sent to *Triage-service* with the *Triage-phone*. When a new *Triage-tag* identification number arrives at *Triage-service*, it inserts a new patient record into the system. All subsequent transactions related to the same *Triage-tag* are then associated with this patient record. Ideally the triage team responsible consists of several medics carrying out evacuation procedures and a clerical officer with *Triage-PC* inserting additional data on the victims and wound types into the patient records.

Based on the near real-time information distributed by the *Triage-service,* all participants involved in the evacuation and recovery of casualties can make informed decisions such as:

- Directing the ambulances to specific hospitals based on the casualty's injuries and the number of critically injured casualties

- Organizing the Emergency Department's (ED) resources to meet the needs of the specific patients directed there

**The system deployment in Lake Vesijärvi in Lahti, Finland**

Each medical person likely to be on the scene was issued a number of *Triage-tags* and a *Triage-phone.* The personnel included triage doctors and nurses as well as conscript military medics, FRC volunteers and airborne rescue unit medics. In the training of the use of the *Triage-phone* simulated a real life situation, where the equipment needs to be deployed on the way to the disaster scene. Typically, it took only a few minutes to explain the use of the Triage-phone and those involved had a short amount of time to practice before they were taken to the scene.

The first triage classifications came from the conscript military medics who were attending the first casualties ashore. Soon more followed from the passenger ship by the airborne medics who had descended there from the helicopter. This information only included the *Triage-tag* identification number, triage class, time stamp and medic identification, the latter also informing where the triage was performed.

The triage information and other tag information (ambulance and position data) were transmitted from Security Authorised Network (TETRA).

The military medics established a Battalion Aid Station (BAS) ashore at the nearest possible landing site. The BAS commander was also the triage responsible doctor. The commander also had a clerical officer present, with the Triage-PC to inform them of the general situation as well as inserting additional victim and wound type data into the patient records. Both were officers of the Finnish Military Reserve. One mission of the Finnish Defence Forces (FDF) is to support other authorities in the disaster or mass casualty situations. The FDF is prepared to give statutory or collaborative agreements on assistance and other support to all levels of society's resources.

In a disaster situation involving civilians, general management is performed by the rescue authority. Medical responsibility for leading an event such as a large scale accident is the duty of the health authority.

**Data collection**

The data logged in the system provided time-tagged information about all events using the system. The time data from the control group (paper-based system) was logged manually.Subjective data on the usefulness of the information provided by the system and the impact on situational awareness was collected by brief interviews with the commanding officers.

**Test setting in Sweden**

The second part of the study was performed at a major airport in Stockholm on the 9th of October 2008**,** with a large aeroplane disaster exercise (Arlanda 2008) in the harsh sub-arctic conditions of Sweden. The full-scale major incident exercise involved a simulated passenger airplane crash landing, with a total of 99 passengers and crew aboard the airplane.

Of those victims, 20 patients were selected as “RFID–patients” for the study. The injured patients received a card describing each individual’s simulated injury profile, which was hung around their necks. After the simulated patients were triaged, each received a triage card. Triage of the simulated patients was based on the injury profile shown on their card (13). An RFID tag was attached to their card. The system used was the same as that employed in the simulated disaster in Finland, except for fact that the simulated victim **sent** the information via the Triage-phone themselves**,** due to the fact that medical personnel were not able to participate in the study. The purpose was to transmit the triage category to all levels of management with the intention to higher situational awareness.

The management of the disaster was achieved by the means of several hierarchical management levels. The highest, the strategic or gold command, was activated by a mass casualty warning and manned in special location away from actual incident, in this exercise, the emergency medical Command Centre SOS Alarm. The dispatch centre referred the injured casualties to three receiving hospitals in the region; one of the hospitals acting as the target hospital. Situational awareness on all management levels was dependent on information that was sent from the airport using various telecommunication methods.

**The system deployment at Arlanda airport, Sweden**

In Sweden, the Merlot system was used mainly for metering and situation information purposes. *Triage-tags* and *-phones* were given to each patient for transmitting each triage performed by the rescue personnel to the *triage-service* for performance analysis. The *Triage-web* was also used to display the situation information at the main evacuation hospital and the command centre. Typically triage data was transmitted from the scene or evacuation **location**, from the airport gate (time stamp when leaving the airport) and when arriving at the evacuation hospital (simulated).

## Data collection

In the Arlanda study, the usability of the new triage system was evaluated with a standard post-test questionnaire. The questionnaire contained eight sections with a total of 27 questions regarding the patients' subjective confidence in the personal use, general use and applicability of the system (Table 1). A section for comments was allowed at the end of the questionnaire. All 17 patients were requested to answer the questionnaire. The technological suitability of the system for field use was measured by analysing the recorded data transfers, tag events and the number of failed data operations.

Table 1

| *Question* | *Agree (n)* | *%* | *Neutral (n)* | *%* | *Disagree (n)* | *%* | *No opinion* |
|---|---|---|---|---|---|---|---|
| 1 *RFID tag reading* | | | | | | | |
| Difficult | 3 | 17.6 | 5 | 29.4 | 8 | 47.0 | |
| Time-consuming | 2 | 11.8 | 5 | 29.4 | 8 | 47.0 | 2 |
| Mostly successful | 7 | 41.2 | 9 | 52.9 | - | 0.0 | 1 |
| 2 *RFID reader operation* | | | | | | | |
| Mostly nonproblematic | 6 | 35.3 | 7 | 41.2 | 3 | 17.6 | 1 |
| Difficult | 2 | 11.8 | 6 | 35.3 | 8 | 47.0 | 1 |
| Reliable | 6 | 35.3 | 6 | 35.3 | 4 | 23.5 | 1 |
| Technical deficiencies | 2 | 11.8 | 8 | 47.0 | 6 | 35.3 | 1 |
| 3 *Application of mTriage software* | | | | | | | |
| Easy to use | 8 | 47.0 | 3 | 17.6 | 6 | 35.3 | |
| Reliable | 6 | 35.3 | 6 | 35.3 | 4 | 23.5 | 1 |
| Deficient | 3 | 17.6 | 4 | 23.5 | 9 | 52.9 | 1 |
| Good compatibility | 8 | 47.0 | 7 | 41.2 | 1 | 5.9 | 1 |
| 4 *RFID patient triage* | | | | | | | |
| More time-consuming than normal | | 0.0 | 5 | 29.4 | 6 | 35.3 | 5 |
| Delayed by technology | | 0.0 | 5 | 29.4 | 6 | 35.3 | 6 |
| Swift and reliable | 4 | 23.5 | 8 | 47.0 | | 0.0 | 5 |
| 5 *RFID versus normal patients* | | | | | | | |
| RFID and normal patients are | | 0.0 | 7 | 41.2 | 2 | 11.8 | 8 |
| RFID patient triage was arduous | | 0.0 | 9 | 52.9 | | 0.0 | 8 |
| Normal patient triage was more arduous | | 0.0 | 9 | 52.9 | | 0.0 | 8 |
| 6 *Training* | | | | | | | |
| Sufficient for using RFID technology | 6 | 35.3 | 6 | 35.3 | 2 | 11.8 | 3 |
| Sufficient for using application | 5 | 29.4 | 4 | 23.5 | 5 | 29.4 | 3 |
| Assistance received while using | 6 | 35.3 | 4 | 23.5 | 3 | 17.6 | 4 |
| Received assistance was sufficient | 5 | 29.4 | 7 | 41.2 | 1 | 5.9 | |
| 7 *Technology and application* | | | | | | | |
| Suitable for personal use | 8 | 47.0 | 5 | 29.4 | 1 | 5.9 | 3 |
| Supports my work | 8 | 47.0 | 6 | 35.3 | 2 | 11.8 | 3 |
| I am ready to use the system | 3 | 17.6 | 9 | 52.9 | 1 | 5.9 | 4 |
| 8 *The system* | | | | | | | |
| Makes my work easier | 2 | 11.8 | 9 | 52.9 | 1 | 5.9 | 5 |
| Increases my efficiency | 3 | 17.6 | 7 | 41.2 | 1 | 5.9 | 6 |
| Helps me perform my tasks | 3 | 17.6 | 8 | 47.0 | 1 | 5.9 | 5 |

**Table 1** The eight-point opinion survey questionnaire with responses to the presented 27 questions

Note: The percentage (%) is the percentage of answers of 17 participants

## Results

### Situational awareness timeline, Finland

Lake Vesijärvi in Lahti

A call to emergency services (112) was made by 10:20am from a passenger ship after running aground. Subsequent damage caused a fire, mildly injuring 20 passengers on board and causing eight to jump into the water. Two divers at the same location received other injuries.

By 10:45am the Battalion Aid Station (BAS) had treatment capabilities; receiving the first two patients, who were divers injured during a search operation. One experienced decompression sickness, whilst the other had an injured limb. One patient was triaged as triage category 2, with the other triaged as category 1 and evacuated to the University Hospital of Turku to receive hyperbaric oxygen therapy. Both casualties were evacuated at time by 10:36am.

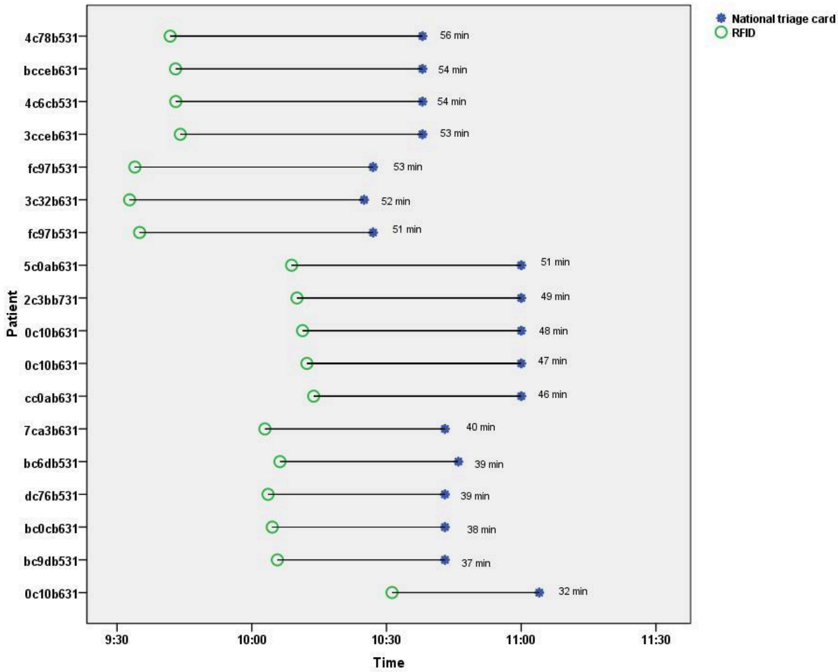


Figure 2. Results in Lake Vesijärvi in Lahti, Finland

Notes:

National triage card: the time when tag information from the patient's first classification at the place of assembly arrived to the Battalion Aid Station.

RFID: the time when mTriage applications patient information reached to the Battalion Aid Station and to the whole emergency management chain.

The total 20 RFID-tag patients were each given the National triage tag. Of the 20 patients, five were classified as triage category 1, five triage category 2 and ten triage category 3. Control group patients (N=18) consisted of five triage category 1, five triage category 2 and eight triage category 3**.** Two patients were unable to be recorded and were excluded from the study results. The average time difference in the BAS between the National Triage tagging and RFID-tags on receiving data was 47 minutes.

Towards the end of the evacuation a situation occurred where one of the yellow (2nd priority) patients was reassessed and their triage category changed to red (1st priority) and all the nearest emergency rooms were already overcome with patients. As this information was available at the scene, the triage officer responsible ordered the patient’s evacuation to another hospital outside the city.

Several hours after the simulation concluded, two “run away” triage green victims were found nearby and were easily recognized for the tags hanging on their neck. After they were fed into the system with the *Triage-phone* the records were complete and no casualties were lost.

**Situational awareness timeline, Sweden**

Stockholm, Arlanda Airport

The exercise started at 10:20 am when the SOS-Alarm emergency line alerted the duty officer at Stockholm county council. A commercial passenger airplane with 99 passengers and crew onboard crashed as it attempted to land 10:20. Regional Disaster Medical Administration (RKML) was put into disaster status.

Spontaneous evacuation began from the airplane and 10:24 am first-aid started by the fire department personnel. The first ambulance arrived at the scene 10:30 am and established their presence as the medical incident officer. 29 casualties were classified as triage category 1 and 2, 61 as category 3 and nine were classified as dead.  The first evacuation of casualties to hospital took place at 10:46 am and the last patient left the scene at 12:55. During the exercise, communication difficulties resulted in inappropriate information being relayed to the strategic level management. Lack of real-time information from disaster site delayed the decision making for EDs to coordinate staff and resources in the hospital.



A total of 20 patients were RFID –tag patients, who also had been given the Smart Tag™.
Of these 20 patients only 17 patients were sent to the exercise target hospital, eight initially classified as triage category 1, three as triage category 2 and six as triage category 3. Control group patients (N=9) consisted of six triage category 1 and three triage category 2 casualties. Mean time difference between information via the Smart Tag® cards and the RFID system was 68 minutes.

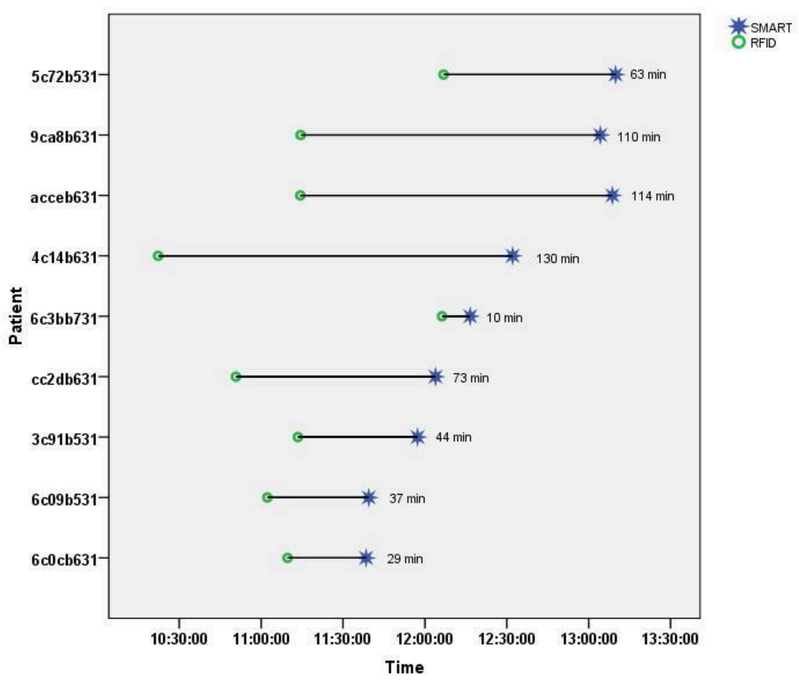


Figure 3. Results in Stockholm, Arlanda Airport, Sweden

Notes:
SMART: the time when Smart Tag® information from the patient's first classification is available at the place of assembly to Capio S:t Görans hospital.
RFID: the time when mTriage applications patient informationis available  to Capio S:t Görans hospital and to the whole emergency management chain.

During the Arlanda 2008 disaster exercise, Capio St Görans hospital set up a Medical Management Center (MMC). Management Centre personnel consisted of a hospital director and included several different sectors, including the Chief Director of the hospital doctors and security. To assess the improvement in situational awareness in the MMC, an interview with the chief director of the hospital was performed after the exercise. According to the post-exercise comments made by the Chief Director, the tested new system provided a timely and true picture of the prevailing situations and greatly improved the general management of the disaster exercise.

### Usability and subjective evaluations of the system

The system users found the RFID mobile system sufficiently easy to use and did not consider using it more arduous than using the traditional paper tags. The users further found the system to support their work and not to be more time-consuming than traditional methods.

## Discussion

The successful use and implementation of continuously evolving mobile and wireless technologies in several fields have also highlighted the opportunities of applying them in the field of healthcare and their potential importance for supporting timely access to decision-critical information (14).

Resource allocation in mass-casualty situations is a significant logistical problem. Particularly under rapidly changing environmental conditions, reliable and timely situational awareness is crucial for making the correct decisions when allocating available resources. Under all conditions, the use of limited and precious resources must be optimised to provide the maximum benefit to the largest possible number of casualties. In mass-casualty situations involving extensive areas, only the ability to collect information on the number of casualties and their triage categories, in different regions of the area, makes efficient and optimal use of limited rescue capacities possible. Patient data was forwarded in Finland on average 47 minutes faster and in Sweden on average 68 minutes faster, using the RFID tags in comparison to the traditional paper method. The system presented here has clear advantages over the traditional method of using **a** paper tag attached to patients. Paper tags are a cheap alternative, but are easily destroyed or lost. Also paper tags encounter problems such as bad handwriting and missing information. An electronic system would be able to answer these problems.

The RFID systems do naturally have their own weaknesses. An obvious one is the need for a reader to access the information. Another is the data ownership and security issues. While the threats current healthcare RFID applications face are not as large as occasionally publicly portrayed, they are real and potentially particularly dangerous for open-loop RFID applications. There has been continuous debate on what rights the system and its users have, for whom are these rights for and how they should be guaranteed, in the healthcare and policymaker communities (15).



As the results show, the RFID triage system is effective in mass-casualty incidents of even up to 100 casualties. In the future, the system will be more valuable when it becomes applicable for other incidents, such as with smaller numbers of casualties or in disasters affecting a large area, such as earthquakes, storms or floods (16).

The RFID system proved easy to use and the improvement of situational awareness in disaster management was significant. Information about the numbers and status or classification of the casualties was available for the coordinating units an hour earlier than with the traditional method with paper tags.

## Conclusion

The conclusion of this study is that RFID is an important tool for providing situation awareness during disaster exercises. More field tests are needed as well as consideration for a plan regarding the system's implementation. The tested system was easy to use, quick, stable and proved to work seamlessly even in harsh field conditions. It surpassed the traditional systems in all respects except simplicity. It also dramatically improved the general view of mass-casualty situations and enhanced medical emergency readiness in a multi-organizational medical setting. Situational awareness in all hierarchical management layers was based on common data generated in real time at incident scene. The timeliness of available information for disaster management was significantly better using the RFID/Merlot medi-system than with the traditional methods.

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