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Lasse Raatiniemi

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LASSE RAATINIEMI

MAJOR TRAUMA IN NORTHERN FINLAND

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Supervised by
Professor Seppo Alahuhta
Doctor Matti Martikainen
Doctor Janne Liisanantti

Reviewed by
Doctor Helena Jäntti
Doctor Torsten Eken

Opponent
Docent Lauri Handolin

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University of Oulu, P.O. Box 8000, FI-90014 University of Oulu, Finland

Abstract

Trauma patients are a significant patient group for emergency medical services (EMS). Not only are injuries a significant cause of death, they also have a significant long-term impact on functionality and quality of life.

Previous studies have shown that the injury-related mortality rate is higher in sparsely populated areas and that the majority of patients die before the arrival of EMS. Intensive care mortality is significant, and half of seriously injured patients develop multiple organ dysfunction. Airway management is one of the most important procedures that EMS provide for a critically injured patient, but making high-quality care available in a sparsely populated area is challenging. Seriously injured patients also appear to benefit from being transported directly to a trauma centre.

In recent years particular attention has been given to the level and availability of EMS. Hospitals' readiness to provide acute surgery is also being reorganised. More information is needed about the frequency, circumstances, outcome and acute care of serious and fatal injuries so that health care resources can be allotted appropriately and requirements for prevention can be identified.

The purpose of this research was to investigate the frequency and circumstances of injury-related deaths in Northern Finland and the prognosis of trauma patients encountered by the Finnish helicopter emergency services (FinnHEMS). A particular objective was to examine differences between rural and urban areas. The National Advisory Committee for Aeronautics (NACA) severity score's ability to predict 30-day mortality was also examined. The fourth part of the study aimed to investigate the pre-hospital airway management performed by non-physicians in Northern Finland.

The study material was comprised of trauma deaths that occurred in Northern Finland in 2007–2011, trauma patients encountered by FinnHEMS units in Northern Finland in 2012–2013, patients encountered by HEMS in Northern Norway in 1999–2009 and a questionnaire regarding pre-hospital airway management to non-physicians.

The study concluded that the rate of trauma deaths is high in Northern Finland, and the influence of alcohol was found in nearly half of pre-hospital trauma death cases. A larger portion of pre-hospital deaths also took place in rural areas. Trauma patients encountered by FinnHEMS units in urban areas who survived to hospital, appeared to have higher 30-day mortality than patients injured in rural areas. The most probable explanation for this difference is that patients injured in urban areas survive to hospital, while trauma patients in rural areas die pre-hospital.

The NACA score was found to reliably predict 30-day mortality. Due to its simplicity, the NACA score can be used to compare patient material from different HEMS bases.

It was found that non-physicians seldom performed airway management. On average, the frequency of performing airway management was low, and there is a need to improve maintenance of skills.

Keywords: airway management, emergency medical services, helicopter emergency medical services, injury, NACA score, pre-hospital emergency medicine, rural, trauma, trauma care

Raatiniemi, Lasse, Vakavat vammautumiset Pohjois-Suomessa.
Oulun yliopiston tutkijakoulu; Oulun yliopisto, Lääketieteellinen tiedekunta; Medical Research Center; Oulun yliopistollinen sairaala; FinnHEMS tutkimus- ja kehittämisyksikkö
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Tiivistelmä

Vammapotilaat ovat merkittävä ensi- ja tehohoidon potilasryhmä. Paisi, että vammautumiset ovat merkittävä kuolinsyy, aiheuttavat ne myös merkittäviä pitkäaikaisvaikutuksia toimintakykyyn ja elämänlaatuun.

Aikaisemmissa tutkimuksissa on osoitettu, että vammakuolleisuus on yleisempää harvaanasutuilla seuduilla ja valtaosa potilaista kuolee jo ennen ensihoidon saapumista paikalle. Tehohoitokuolleisuus on merkittävää ja puolet vaikeasti loukkaantuneista potilaista kärsii monielinvauriosta. Ensihoidon tärkeimpiä tehtäviä kriittisesti vammautuneilla on hengitystien varmistaminen, mutta korkeatasoisen hoidon saatavuus harvaanasutulla seudulla on haasteellista. Vaikeasti vammautuneet potilaat näyttävät myös hyötyvän kuljetuksesta suoraan lopulliseen hoitopaikkaan.

Viime vuosina ensihoidon tasoon ja saatavuuteen on kiinnitetty erityistä huomiota. Lisäksi sairaaloiden päivystysvalmiuden uudelleenorganisointi on käynnissä. Lisätietoa tarvitaan vakavien ja kuolemaan johtavien vammojen esiintyvyydestä ja olosuhteista, ennusteesta sekä akuuttihoidon toteutumisesta, jotta terveydenhuollon resursseja voitaisiin kohdentaa tarkoituksenmukaisesti ja ennaltaehkäisyn tarpeet voitaisiin tunnistaa. Tämän tutkimuksen tarkoituksena oli selvittää vammakuolemien esiintyvyyttä ja olosuhteita Pohjois-Suomessa sekä suomalaisten lääkintä- ja lääkärihelikopteriyksikköjen (FinnHEMS) kohtaamien vammapotilaiden ennustetta. Erityisenä tavoitteena oli tutkia maaseutu- ja kaupunkialueiden eroja. Lisäksi tutkittiin National Advisory Committee for Aeronautics (NACA)- vaikeusasteluokittelun kykyä ennustaa 30 päivän kuolleisuutta. Neljännen osatyön tavoitteena oli tutkia ensihoitajien suorittaman hengitystien varmistamisen käytäntöä Pohjois-Suomessa.

Tutkimusaineisto koostui vuosina 2007–2011 Pohjois-Suomessa tapahtuneista vammakuolemista, FinnHEMS:in yksiköiden kohtaamista vammapotilaista Pohjois-Suomessa vuosina 2012–2013, Pohjois-Norjan pelastushelikopterin kohtaamista potilaista vuosina 1999–2009 sekä ensihoitajille tehdystä kyselytutkimuksesta hengitystien hallintaan liittyen.

Tutkimuksessa todettiin, että kuolemaan johtaneiden vammojen esiintyvyys on korkea Pohjois-Suomessa. Lisäksi havaittiin, että lähes puoleen sairaalan ulkopuolella tapahtuneisiin vammapotilaiden kuolintapauksiin liittyi alkoholi. Maaseudulla myös suurempi osa menehtyi sairaalan ulkopuolella. FinnHEMS:in yksiköiden kaupunkialueella kohtaamilla vammapotilailla, jotka selvisivät sairaalaan, havaittiin viitettä korkeampaan 30 päivän kuolleisuuteen verrattuna maaseudulla vammautuneihin. Ero johtuu todennäköisemmin siitä, että kaupunkialueella vammautuneet ehtivät sairaalaan kun taas maaseudulla vammapotilaat kuolevat jo ennen ensihoitopalvelun saapumista.

NACA-vaikeusasteluokittelun todettiin ennustavan luotettavasti 30 päivän kuolleisuutta. Yksinkertaisuutensa vuoksi se soveltuu potilasmateriaalin vertailemiseen eri tukikohtien välillä.

Ensihoitajan suorittama hengitystien varmistaminen havaittiin olevan harvinaista. Keskimääräisesti suoritteita tapahtui harvoin, ja taitojen ylläpitämisessä oli parantamisen varaa.

Asiasanat: ensihoitolääketiede hengitystien varmistaminen, ensihoitopalvelu, lääkintähelikopterijärjestelmä, maaseutu, NACA-vaikeusasteluokitus, trauma, traumahoito vammat

To my family

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August 2016 Lasse Raatiniemi

Abbreviations

AIS	Abbreviated Injury Scale
ALS	Advanced life support
ARIA	Accessibility/remoteness index of Australia
ASA-PS	American Society of Anaesthesiologists Physical Status
AUC	Area under curve
BLS	Basic life support
BVMV	Bag-valve-mask ventilation
CPR	Cardiopulmonary resuscitation
ED	Emergency department
EMS	Emergency medical services
ER	Emergency room
ETI	Endotracheal intubation
FCDR	Finnish Cause of Death Register
FinnHEMS	Finnish helicopter emergency medical services
GCS	Glasgow coma scale
GOS	Glasgow outcome scale
GP	General practitioner
HE	High energy
HEMS	Helicopter emergency medical services
ICD	International Classification of Diseases
ICU	Intensive care unit
ISS	Injury Severity Score
LE	Low energy
LOS	Length of stay
MEES	Mainz Emergency Evaluation Scoring System
NACA	National Advisory Committee for Aeronautics
NISS	New Injury Severity Score
OR	Operating room
PHAAM	Pre-hospital advanced airway management
RCT	Randomised controlled trial
ROC	Receiver operating characteristics curve
RTS	Revised Trauma Score
SAD	Supraglottic airway device
TBI	Traumatic brain injury
T-RTS	Triage-Revised Trauma Score

List of original publications

This thesis is based on the following publications, which are referred to throughout the text by their Roman numerals:

I Raatiniemi L, Steinvik T, Liisanantti J, Ohtonen P, Martikainen M, Alahuhta S, Dehli T, Wisborg T & Bakke HK (2016) Fatal injuries in rural and urban areas in northern Finland: a 5-year retrospective study. Acta Anaesthesiol Scand 60(5): 668–76.

II Raatiniemi L, Liisanantti J, Niemi S, Nal H, Ohtonen P, Antikainen H, Martikainen M & Alahuhta S (2015) Short-term outcome and differences between rural and urban trauma patients treated by mobile intensive care units in Northern Finland: a retrospective analysis. Scand J Trauma Resusc Emerg Med 23(1): 91.

III Raatiniemi L, Mikkelsen K, Fredriksen K & Wisborg T (2013) Do pre-hospital anaesthesiologists reliably predict mortality using the NACA severity score? A retrospective cohort study. Acta Anaesthesiol Scand 57(10): 1253–1259.

IV Raatiniemi L, Lankimaki S & Martikainen M (2013) Pre-hospital airway management by non-physicians in Northern Finland -- a cross-sectional survey. Acta Anaesthesiol Scand 57(5): 654–659.

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1 Introduction

It is estimated that 5.1 million people died from injuries and that injuries accounted for 9% of the burden of diseases worldwide in 2012 (WHO). In Finland the death rate from unintentional injuries is twice as high as in other Nordic countries, which can be explained by the higher incidence of fatal home and leisure-time injuries (Ministry of Social Affairs and Health 2013). Especially rural areas have been documented as having a higher death rate from injuries, and the reasons for that are multifactorial (Peek-Asa *et al.* 2004). The trauma system, including prevention, pre-hospital emergency care, trauma hospitals and rehabilitation, is an important factor in seeking to reduce mortality and morbidity in trauma (American College of Surgeons 2014, Lansink & Leenen 2007).

Recognition and triage of a severely injured patient to the right level of care and skills in trauma care are challenges faced by trauma care in the Nordic countries (Kristiansen *et al.* 2010). Pre-hospital airway management and definition of the time windows for pre-hospital critical care procedures are two of the five top priorities in physician-provided pre-hospital emergency care (Fevang *et al.* 2011). Anaesthesiologist-staffed units have been shown to have excellent success rates in pre-hospital endotracheal intubation (Lockey *et al.* 2013, Lossius *et al.* 2012b, Rognas *et al.* 2013a). These units are not always available, however, especially in sparsely populated areas, and airway management has to be carried out by non-physicians with low exposure to critical care procedures. Nevertheless the standard of pre-hospital advanced airway management (PHAAM) should be as good as in an emergency department (Lockey *et al.* 2014).

During the last several years, much effort has been put into developing emergency medical services (EMS), especially helicopter emergency services (HEMS), but the benefits of HEMS in trauma are still continuously debated (Galvagno *et al.* 2013). EMS are a part of the chain of survival, but more data on their role in trauma care is needed, especially in rural areas. The Norwegian Air Ambulance Services have used the National Advisory Committee for Aeronautics (NACA) score to measure the overall severity of injuries in the patient material amongst different helicopter bases for several years. However, there are no studies from Norway that have investigated how well NACA scores can predict outcome.

Data on the demographics of severe injuries and their distribution in rural and urban areas in Northern Finland are needed in order to develop trauma systems and especially EMS. General data are also needed to be able to plan further studies in trauma care and HEMS. While airway management is probably the most critical intervention in pre-hospital care, more studies are indicated to find areas that need improvement in clinical practice.

The present study sought to obtain data on trauma care in Northern Finland. A particular aim was to study rural-urban differences in fatal injuries and in trauma treated by HEMS units. In addition, the purpose was to obtain baseline data on pre-hospital airway management by non-physicians and determine how well NACA scores can predict mortality in patients treated by EMS.

2 Review of the literature

2.1 Trauma: burden of injuries and mortality worldwide and in Finland

Trauma is the leading cause of death in younger age groups worldwide and it causes many lost life years (WHO). Low- and middle-income countries have higher death rates than high-income countries; this has been suggested to result from a combination of a higher injury rate and a lower level of care (Mock *et al.* 2004, Mock *et al.* 2005). There are also reported differences in outcomes between regional areas and hospitals (Baker *et al.* 1988, Bakke *et al.* 2013, Kristiansen *et al.* 2014, Mullins *et al.* 2006) In nationwide studies from Norway, rural areas had higher trauma mortality and more pre-hospital deaths due to trauma in the working-age population and among children (Kristiansen *et al.* 2012a, Kristiansen *et al.* 2014). Especially the northernmost county, Finnmark, had the highest death rate. Similarly, in Italy, the southern and central parts of the country had higher in-hospital trauma mortality than the northern part (Di Bartolomeo *et al.* 2008). Although the study did not aim to find the causes of mortality differences, the authors discussed that trauma centres and EMS are better represented in the northern part of the country.

Finland has the fourth highest death rate in unintentional injuries in the European Union and it is higher than in the other Nordic Countries. Mortality resulting from unintentional injuries is nearly twice as high in Finland compared to the average in the European Union. This can be explained by the high proportion of home and leisure-time injuries in Finland (Ministry of Social Affairs and Health 2013).

Falls have replaced road traffic incidents as the most important cause of severe injury in Finland (Kannus *et al.* 2001). The age-standardised death rate from falls in men has risen slightly between 1971 and 2009 while in women it has declined from 32 deaths per 100,000 inhabitants per year to 16 (Korhonen *et al.* 2011). In a study of traumatic brain injuries (TBI) in the Nordic countries, head injury mortality was reported to be twice as high in Finland compared with the other Nordic Countries in 1987–2001. Finland also had the highest number of operations for traumatic brain injuries (TBI) among the Nordic countries (Sundstrom *et al.* 2007).

2.2 Rural vs. urban trauma

2.2.1 Definition of rurality

Various definitions of rural trauma have been used, such as population density, centralisation, settlement density or access to the scene (Fatovich & Jacobs 2009, Gonzalez *et al.* 2007, Kristiansen *et al.* 2014).

The American College of Surgeons defines trauma care as rural if optimal care of injured patients is limited by geography, weather, distance or resources (American College of Surgeons 2014). Australian trauma outcome studies have used the AREA (Accessibility/Remoteness Index of Australia). It describes the ease or difficulty of accessing services. There are five classes of remoteness: major cities, inner regional, outer regional, remote and very remote. The index is used by the Australian Bureau of Statistics (Fatovich & Jacobs 2009).

In a Norwegian population-based trauma study, population density, centrality and settlement density were used to measure the grade of rurality (Kristiansen *et al.* 2014). In that study population density best predicted areas of high risk.

In a Scottish trauma outcome study, Scottish Ambulance Service response time standards for population density were used to define rural and urban areas (McGuffie *et al.* 2005). Also the size of the town, measured by the number of inhabitants, has been used to define rural areas (Zwerling *et al.* 2005).

2.2.2 Rural-urban difference in trauma demographics

Rural and urban traumas have differences. The incidence of severe or hospitalisation-requiring injuries has been reported to be higher in rural areas (Boland *et al.* 2005, Coben *et al.* 2009, Jiang *et al.* 2007, Jiang *et al.* 2007, Mitchell & Chong 2010). For example, road traffic incidents, drownings, suicides and occupational injuries have been reported to be more common in rural areas. Contrary to rural areas, the occurrence of falls and injuries resulting from assaults has been reported to be more common in urban areas (Fatovich & Jacobs 2009, Fatovich & Jacobs 2009, McGuffie *et al.* 2005, Peek-Asa *et al.* 2004).

2.2.3 Mortality

The higher injury-related death rate in rural areas compared with urban areas has been reported in several studies (Baker *et al.* 1987, Baker *et al.* 1988, Bakke *et al.*

2013, Fatovich & Jacobs 2009, Kristiansen *et al.* 2012a, Kristiansen *et al.* 2014, Lagace *et al.* 2007, Peek-Asa *et al.* 2004, Rogers *et al.* 1997, Rogers *et al.* 1999, Wisborg *et al.* 2003) In particular, a high rate of pre-hospital deaths has been reported in rural areas (Bakke *et al.* 2013, Fatovich & Jacobs 2009, Fatovich *et al.* 2011b, Kristiansen *et al.* 2012a, Kristiansen *et al.* 2014, Rogers *et al.* 1997, Simons *et al.* 2010). Rogers *et al.* reported in their study investigating fatal injuries that a larger proportion of rural patients (72% vs. 41%) died on-scene than urban patients. Rural victims were older and had more comorbidities, but they had lower injury severity scores than urban victims (Rogers *et al.* 1997).

More severe traffic incidents due to higher speeds and types of collisions, differences in the types of vehicles and safety-belt use and exposure to farm machinery and fishery, firearms and water areas are possible explanations for higher death rates in rural areas (Baker *et al.* 1987, Boland *et al.* 2005, Gonzalez *et al.* 2007, Peek-Asa *et al.* 2004, Zwerling *et al.* 2005).

Differences in outcomes in rural and urban traumas can also be explained by factors other than differences in the types of traumas. Rural areas generally have poorer access to EMS and advanced life support (ALS) units and there are longer transport times to definitive care (Leonhard *et al.* 2015, Muelleman *et al.* 2007, Simons *et al.* 2010). Especially in traffic incidents occurring in rural areas, long pre-hospital times have been associated with higher mortality (Clark *et al.* 2013). Finally, it has been assumed that the level of care is lower in rural areas (Esposito *et al.* 1995, Gomez *et al.* 2010, Leonhard *et al.* 2015, Peek-Asa *et al.* 2004).

When the mortality of trauma patients who survived to hospital was compared, the in-hospital mortality was not higher for rural patients, highlighting the importance of the factors in the trauma system and pre-hospital phase in rural traumas (Fatovich *et al.* 2011a, McCowan *et al.* 2007, McGuffie *et al.* 2005, Simons *et al.* 2010).

2.3 Trauma mortality, injury and patient-related factors

2.3.1 Mechanisms and types of injuries

Inclusion criteria in trauma studies vary. For example some studies have excluded low energy (LE) falls in older age groups (Bakke & Wisborg 2011, Bakke *et al.* 2013). The mechanism of injury alone does not predict the probability that a patient is severely injured (Boyle 2007). Many factors, such as seatbelt use, airbag deployment and velocity changes in traffic incidents have been associated with injury severity (Staff *et al.* 2014).

The dominating types of injury can be divided into blunt and penetrating. The treatment and diagnosis of these injuries often differ. It is also known that patients with penetrating trauma die within one hour after injury more often than patients with blunt trauma (Demetriades *et al.* 2004, Pfeifer *et al.* 2016).

In multiple traumas, a head injury is the most important cause of death (Acosta *et al.* 1998, Goris & Draaisma 1982, Pfeifer *et al.* 2009). It is a strong predictor of mortality in trauma patients treated in an intensive care unit (ICU) (Brattstrom *et al.* 2010). A Finnish study group that investigated severe paediatric injuries found that most of the injuries resulting from road traffic incidents were due to a blunt head injury and the majority of deaths occurred on the scene or within 6 hours (Suominen *et al.* 1998).

In motor vehicle incidents, the type of collision affects injury severity. For example, injuries are more severe and multiple injuries are more common in side-impact crashes than in other types of incidents (McLellan *et al.* 1996, Weninger & Hertz 2007). Also the type of vehicles involved in the incident has an impact on injury severity. Collisions between sedans and light trucks with a high mass ratio increase the incidence of thorax and abdominal injuries, as well as severe brain injuries (Siegel *et al.* 2001).

The population in western countries is ageing and falls have become the leading cause of injury-related death (Anderson & Hussey 2000, Korhonen *et al.* 2012). LE falls do not cause only hip fractures. LE trauma can lead to severe injuries, and especially in this group of patients, undertriage is common. (Rehn *et al.* 2009, Rehn *et al.* 2012, Velmahos *et al.* 2001). A study from the USA analysed all EMS dispatch calls where the patient later died (Dean *et al.* 2014). In that study 29% of the patients were able to talk when encountered by EMS and of these, 19% died within 48 hours in-hospital. These “talk-and-die”-patients were older and more often injured by falls, compared with patients with obvious severe injuries.

2.3.2 Comorbidities and age

Age is an independent risk factor for trauma mortality even after less severe trauma (Bergeron *et al.* 2004, Bergeron *et al.* 2005, Hildebrand *et al.* 2015, Jones *et al.* 2014, Meisler *et al.* 2011). Age > 50 years was a significant predictor of 30-day mortality in a Norwegian study investigating trauma patients in an ICU (Ulvik *et* *al.* 2007). In another Scandinavian study, age > 55 years had 4.4 odds ratio for 30-day mortality (Brattstrom *et al.* 2010).

The trauma mortality rate has also been shown to be higher in a population with comorbidities (Bergeron *et al.* 2006). Mortality also remains higher compared with the general population long after injury (Brattstrom *et al.* 2012, Davidson *et al.* 2011).

2.3.3 Alcohol and other substances

Alcohol is an important contributing factor in injuries (Kowalenko *et al.* 2013) and has been reported as the most common psychoactive substance in traffic incidents that cause severe injuries. In Europe, the rate of alcohol abuse in severe traffic incidents has been reported to be 18 to 43% and the rate of combined alcohol and drug use, from 2 to 13%. (Legrand *et al.* 2013). A high proportion of alcohol (from 17% to 59%) and drug use (22 to 44%) has also been reported in severely injured patients admitted to trauma centres (Bowley *et al.* 2004, Diaz-Contreras *et al.* 2008, Stewart *et al.* 2003). The influence of alcohol prior to injury has been associated with better survival in TBI (Plurad *et al.* 2010, Salim *et al.* 2009, Talving *et al.* 2010), however, but the connection is still contradictory (Opreanu *et al.* 2010).

Adolescents with alcohol consumption as a part of their lifestyle have been shown to have increased risk for fatal injury and, especially in the rural population, their alcohol consumption has been reported to be higher (Jiang *et al.* 2008).

2.3.4 Socioeconomic factors

Socioeconomic factors such as low education or income level are risk factors for trauma (Brattstrom *et al.* 2015, Newgard *et al.* 2011). For example, in a Norwegian population-based study, there was an inverse relationship between the municipal proportions of high-income earners and road traffic deaths (Kristensen *et al.* 2012).

The impact of socioeconomic status on the incidence of injuries varies at different ages (Engstrom *et al.* 2002). A rural location may exacerbate socioeconomic disadvantages, and socioeconomic status has been reported to be a stronger factor for mortality than rural location by itself (Smith *et al.* 2008).

There is also a relationship between socioeconomic factors and intentional injuries. In Finland, for example, the number of suicides in boys increased during economic depression (Mattila *et al.* 2005).

2.4 Trauma system and outcome

A trauma system is an organised approach to the care of trauma patients (Cameron *et al.* 2014, Kristiansen *et al.* 2010, Kristiansen *et al.* 2012b, Lansink & Leenen 2007). Inclusive trauma systems are designed to treat all traumas in a geographical area and all acute care facilities with emergency departments in the area are part of the trauma system. In an inclusive trauma system there is responsibility for the entire chain of trauma care, including pre-hospital trauma care and rehabilitation, in the geographical area. In contrast to this, in an exclusive trauma system the most severe injuries are treated in specialized trauma centres and most of the other acute care facilities treat minor injuries without trauma care preparation or interaction with the specialized centres. More severely injured patients are received on occasion in these non-trauma centres. (American College of Surgeons 2014, Lansink & Leenen 2007).

Trauma systems with trauma centres have been shown to reduce mortality and improve functional outcome after major trauma (Brown *et al.* 2010b, Cameron *et al.* 2008, Dinh *et al.* 2014, Gabbe *et al.* 2012, Hildebrand *et al.* 2015, Lansink & Leenen 2007, MacKenzie *et al.* 2006). A meta-analysis from North America found that implementing trauma systems has led to a 15 % reduction in trauma mortality (Celso *et al.* 2006). Nevertheless, comparisons of trauma systems in different countries have been demonstrated as being problematic (Nathens *et al.* 2004).

Patients treated in trauma centers with a larger volume have been reported to have better survival rates than those treated in smaller ones (Ala-Kokko *et al.* 2009, MacKenzie *et al.* 2006, Minei *et al.* 2014) and they also have better functional outcomes (Metcalfe *et al.* 2014). An early transfer of severely injured patients from a local hospital to a trauma centre has also been associated with increased survival (Meisler *et al.* 2010). A Norwegian study reported an improved survival in neurotrauma (Sovik *et al.* 2014). Authors discussed several factors such as increased neurosurgical presence and competence, structured training and increased HEMS capacity, which may underlie these findings.

There are variations in the level of development of trauma system between different countries, which is also true in Europe (Balasubramanian *et al.* 2016, Dehli *et al.* 2015, Handolin *et al.* 2006, Kristiansen *et al.* 2010, Leppäniemi 2005).

2.4.1 Trauma training and trauma team

The number of hospitals which treat trauma patients in the Nordic countries is high relative to the population (Kristiansen *et al.* 2010). Due to the sparse population and low frequency of severe trauma, training is of importance. Teamwork skills are especially essential on a trauma team (Cole & Crichton 2006). Local training has proved to be feasible and simulation training makes it possible to train for factors that occur infrequently (Wisborg *et al.* 2006). Hjortdahl *et al.* performed interviews among trauma team members regarding non-technical skills in four different hospitals in Norway. They concluded that the members of the trauma teams experienced leadership as a very important factor for a successful trauma team, and more training was deemed necessary (Hjortdahl *et al.* 2009).

Aside from undertriage, overtriage should also be minimised. Participation on a trauma team requires resources and an overtriage grade as high as 92% has been reported (Stordahl *et al.* 2015). One possibility for realising a more adequate use of resources is a two-tiered trauma team activation (Davis *et al.* 2010, Kouzminova *et al.* 2009, Rehn *et al.* 2012).

2.5 Role of pre-hospital care in trauma and trauma mortality

Pre-hospital emergency medical services in trauma care can be divided into basic (BLS) and advanced life support (ALS). BLS includes medical care provided by bystanders or BLS units to assure vital functions until the patient is transported to the appropriate medical care. ALS includes the use of methods such as medication and intubation and is provided by paramedics or physicians (Ryynanen *et al.* 2010). The highest tier of EMS is physician-staffed units, normally staffed by anaesthesiologists. In addition to ALS skills, these units can perform bed-side diagnostics and even some procedures that have traditionally been performed in hospitals (Gellerfors *et al.* 2016).

The recognition of severely injured patients, transportation to the right level of care, and therapeutic interventions have been considered the most important factors in pre-hospital trauma care (American College of Surgeons 2014, Kristiansen *et al.* 2010).

2.5.1 Time from injury to death

Traditionally, trauma deaths have been described as following tri-modal distribution: immediate deaths, early deaths (within hours after injury) and late deaths (later than one week after injury) (Trunkey 1983). Newer studies (Bakke & Wisborg 2011, de Knegt *et al.* 2008, Demetriades *et al.* 2005, Evans *et al.* 2010, Pang *et al.* 2008), however, have demonstrated that mortality after trauma may be more bi-modal than tri-modal.

A high Injury Severity Score (ISS) and a need for a mass transfusion are associated with early mortality (<24 hour), and a head injury, with death 1–6 days after injury (Abdelrahman *et al.* 2014, Lefering *et al.* 2012). Pre-hospital deaths most commonly result from traffic incidents, and deaths that occur later in the hospital from falls especially in older age groups (Morrison *et al.* 2015).

While early deaths predominate, the role of EMS and acute care in-hospital are crucial for a better outcome.

2.5.2 Pre-hospital times in trauma

Definition of time intervals

Pre-hospital time intervals consist of time from injury to emergency call, time from emergency call to alarm, time from alarm to arrival at the scene, on-scene time (time from arrival at the scene to leaving the scene), transport time to hospital and delivery time (arrival at hospital to transfer to care) (Carr *et al.* 2006).

Pre-hospital times and mortality

Traditionally it is believed, that the prognosis after trauma is better, if the definitive care is initiated within 60 minutes after injury (Cowley 1975, Lerner & Moscati 2001, Rogers *et al.* 2015). Despite the fact that the golden hour is very well known in pre-hospital trauma care, the evidence is limited (Harmsen *et al.* 2015, Lerner & Moscati 2001, Rogers *et al.* 2015). Several studies have failed to show correlation between pre-hospital times and mortality (Blackwell *et al.* 2009, Harmsen *et al.* 2015, Petri *et al.* 1995). Lerner *et al.* reviewed 2,925 trauma cases and observed that total pre-hospital time was not associated with mortality, contrary to the ISS, the Revised Trauma Score (RTS) and age (Lerner *et al.* 2003). In a study by Petri et al., longer pre-hospital times did not correlate with outcome either. Indeed, they found a higher mortality with shorter on-scene, transport and total pre-hospital times (Petri *et al.* 1995). With the exception of cardiac arrest, there is no documentation showing that a pre-hospital response time of less than eight minutes would be crucial in trauma (Pons & Markovchick 2002).

In a population-based study from Norway, transport time had a model-dependent association with mortality (Roislien *et al.* 2015). In contrast, there are studies that document a positive impact of shorter time intervals (Clark *et al.* 2013, Dinh *et al.* 2013, Swaroop *et al.* 2013).

In the subgroups of trauma patients with penetrating injuries and hypotension, the evidence supports short pre-hospital times (Harmsen *et al.* 2015, McCoy *et al.* 2013, Newgard *et al.* 2015). Also patients with severe traumatic brain injury have been reported to benefit from short pre-hospital time (Dinh *et al.* 2013, Tien *et al.* 2011).

Kotwal *et al.* recently published a study comparing the outcomes of combat casualties transported by helicopter within 60 minutes vs. more than 60 minutes from the call to arrival at the treatment facility (Kotwal *et al.* 2015). After implementing a mandate of faster helicopter transportation, casualties that previously would have died in the field now arrived alive at a treatment facility more often.

Only a few studies from the Nordic countries have reported the impact of pre-hospital time on trauma mortality (Brattstrom *et al.* 2010, Henriksson *et al.* 2001). In a Swedish study investigating the mortality and morbidity of ICU-treated trauma patients, a pre-hospital time longer than 60 minutes predicted an increased 30-day mortality (Brattstrom *et al.* 2010). In a retrospective analysis of fatal traffic incidents in Northern Sweden, a large proportion of the patients with an ISS < 50 did not receive optimal care in time. Most of the victims were found too late and transport time had an impact on survival (Henriksson *et al.* 2001).

Studies of pre-hospital times and outcome should be interpreted with caution, as different definitions of time intervals have been used. It is recommended that time from injury to emergency call, transport time and time until a trauma patient receives definitive care in-hospital are taken into account when interpreting trauma studies (Fleet & Poitras 2011). Collecting the dataset described by the Utstein template for uniform reporting of data following major trauma is recommended in trauma studies (Ringdal *et al.* 2008).

2.5.3 Trauma first aid

Evidence of the impact of bystander-provided first aid on trauma mortality is limited (Tannvik *et al.* 2012). Studies based on autopsies have stated that a potential life-saving benefit of 2 to 5% could have been gained by opening the airway or/and controlling external bleeding (Ashour *et al.* 2007). In a study from Iraq with long pre-hospital times, mortality was lower if trauma victims received first aid by a trained layperson compared with no first aid at all (Murad & Husum 2010). Results should be interpreted with caution in the Nordic Countries, as this study was done in a war area with a high number of penetrating injuries.

Other important questions in addition to possible benefits of bystander-provided first-aid are how often it is performed and if it is performed correctly. The proportion of trauma patients receiving first aid has varied between 11 and 65% (Tannvik *et al.* 2012). In a large volume of material from North America, traumatic injury was the most common reason for bystanders giving first aid (Faul *et al.* 2016). In a recently published observational study from Northern Norway, Bakke *et al.* reported that a majority of trauma patients received first aid correctly. Previous training in first aid had a positive impact on the quality of the first aid (Bakke *et al.* 2015).

2.5.4 Notification of the incident

Lacking observation of an injury can cause a long delay before care, especially in rural areas (Danne 2003, Peek-Asa *et al.* 2004). In a Finnish study, the time from a traffic incident to notification of it was especially long on roads with low traffic volume, incidents at night, single-vehicle incidents or collisions with an animal (Sihvola *et al.* 2001). An automatic crash notification system has been reported to be able to reduce fatalities in road traffic incidents from 2 to 11% (Clark & Cushing 2002, Lahausse *et al.* 2008). It has also been demonstrated to be feasible in dispatching HEMS earlier to the scene of injury (Matsumoto *et al.* 2016).

A long delay in notification of injury also plays an important role in other types of injuries not caused by traffic incidents, such as accidental hypothermia or hyperthermia. In a Swedish study, the majority of deaths due to hypothermia occurred in rural areas (Brandstrom *et al.* 2012). Also in deaths occurring in a sauna, the victims are typically found alone and have been under the influence of alcohol (Rodhe & Eriksson 2008).

2.5.5 Dispatch in trauma

Early recognition of high-energy trauma or a severely injured patient is important during the dispatch call (American College of Surgeons 2014). An appropriate level of care should be dispatched as early as possible. Especially the importance of HEMS dispatching is debated. HEMS can be dispatched simultaneously with other EMS units or alternatively after a request from other EMS or rescue units on-scene.

HEMS dispatching is dependent on operational procedures, but also on organisational factors such as training of the dispatcher and EMS providers (Wigman *et al.* 2011). Dispatch criteria have been criticised for lack of accuracy and for having caused overuse of HEMS. On the other hand, it has been reported that accuracy in dispatching HEMS is low (Wisborg *et al.* 2015). In a systematic review, loss of consciousness was the most accurate criterion for a HEMS dispatch (Ringburg *et al.* 2009). Simultaneous dispatch of HEMS with EMS has been suggested to reduce on-scene time (Gries *et al.* 2014). However, the superiority of primary or secondary dispatching of HEMS is still being debated (McQueen *et al.* 2015b).

2.5.6 Recognition of severe injuries

One of the important successes in trauma systems is that the patients are triaged to the correct level of care in the shortest possible time (Cameron *et al.* 2014). Direct admissions from scene to trauma centre have been associated with better survival (Haas *et al.* 2012, Hartl *et al.* 2006, Sampalis *et al.* 1997). However, the topic remains still debated (Mans *et al.* 2016, Pickering *et al.* 2015).

Triage of a trauma patient for the right level of care requires the use of protocols and that these protocols are familiar to the EMS providers. Pre-hospital triage can be based on physiological parameters, an injury mechanism, comorbidities, age or a combination of these (Lecky *et al.* 2014, Sasser *et al.* 2012). But triage tools have their limitations due to over- and undertriage.

An example of the difficulty of field triage is blunt injuries. They often have an occult nature and do not become apparent before imaging has been performed in-hospital (Hasler *et al.* 2012, Kirves *et al.* 2010). The ability to predict severe injuries in a pre-hospital setting is dependent on the training level of the EMS providers as well. The possibility of online guidance from a physician is considered important (American College of Surgeons 2014). On the other hand, pre-hospital triage performed by physicians has been reported to reduce undertriage (Bouzat *et al.* 2015).

Delays in trauma centre admission are common especially in TBI patients. Raj *et al.* reported that factors such as a low-energy trauma mechanism, no consultation (call or on-scene) with an EMS physician and alcohol intoxication caused delay to trauma centre admission (Raj *et al.* 2013).

2.5.7 Level of pre-hospital trauma care

The impact of ALS on survival is still debated (Jayaraman *et al.* 2014). There is only one published randomised controlled trial (RCT) that has compared survival in blunt trauma patients treated either by flight paramedics or physicians (Baxt & Moody 1987a). In addition there are several controlled studies on the level of pre-hospital care and outcome in trauma (Iirola *et al.* 2006, Pakkanen *et al.* 2016, Stiell *et al.* 2008, Suominen *et al.* 2000, Botker *et al.* 2009, Di Bartolomeo *et al.* 2001, Di Bartolomeo *et al.* 2005, Frankema *et al.* 2004, Garner *et al.* 1999, Hamman *et al.* 1991, Iirola *et al.* 2006, Lechleuthner *et al.* 1994, Lee *et al.* 2003, Oppe & De Charro 2001, Osterwalder 2003, Pakkanen *et al.* 2016, Roudsari *et al.* 2007b, Schwartz *et al.* 1990, Stiell *et al.* 2008, Suominen *et al.* 1998, Suominen *et al.* 2000).

Several studies have reported that ALS is associated with a worse outcome than BLS in trauma (Ryynanen *et al.* 2010, Sampalis *et al.* 1993, Stiell *et al.* 2008). Especially in penetrating injuries, BLS has been shown to be a sufficient level of care if the distance to hospital is short (Ryynanen *et al.* 2010, Seamon *et al.* 2013). For some patients with penetrating injuries, however, ALS procedures such as pre-hospital thoracotomy have been life-saving (Davies & Lockey 2011). Also in urban area pre-hospital interventions such as ETI, tourniquets and needle decompression have been shown to reduce the mortality of the most severely injured trauma patients (Meizoso *et al.* 2015).

Some studies show a positive effect of ALS in cases of head trauma (Berlot *et al.* 2009, Davis *et al.* 2005, Frankema *et al.* 2004, Franschman *et al.* 2012, Garner *et al.* 2015).

One of the most extreme approaches to studying the impact of pre-hospital care on trauma survival is to compare private transportation with transportation by EMS. In such studies, private transportation has been associated with lower mortality (Huber *et al.* 2016, Johnson *et al.* 2013). Time to diagnostics and time spent in the trauma room have, however, been reported to be longer if the private transport has been used. Comparing transportation modes include several biases. Firstly, the trauma mechanism may be different between groups. Secondly, patients with very severe injuries may survive to hospital via EMS and are present only in the EMS group. Thirdly, patients that use private transportation are referred to different kinds of hospitals than those transported by EMS (Huber *et al.* 2016).

When comparing the studies and drawing conclusions on the benefit of the level of EMS, it is important to keep in mind that the performance and structure of EMS varies internationally (Roudsari *et al.* 2007a). On the other hand, the results of studies performed in urban EMS are poorly generalisable to rural areas such as in the Nordic countries.

Many studies have concentrated on comparing the outcome of patients that have survived to hospital and excluded patients that died in pre-hospital environment. Panel studies of preventable trauma deaths have reported a relatively large proportion of preventable pre-hospital trauma deaths, however, even in urban areas (Davis *et al.* 2014, Kleber *et al.* 2013), which highlights the importance of a high level of pre-hospital trauma care. Physician involvement in pre-hospital trauma care has especially been associated with a lower incidence of early fatalities compared with the care provided by ALS paramedics (Roudsari *et al.* 2007b).

2.5.8 HEMS

The role of HEMS in trauma care is not well studied. Randomised controlled studies are lacking and the heterogeneity in the methods used in the studies is a challenge, when interpreting the results. It has been suggested that the benefits of HEMS in trauma result from the faster transport and the better competence of HEMS providers compared with EMS providers on the ground, and that HEMS is part of an organised trauma system (Galvagno 2013).

It has recently been reported that the impact of HEMS on survival is dependent on many factors, such as the degree of urbanisation, utilisation of HEMS, injury severity and access to a trauma centre in the geographical area they operate in (Brown *et al.* 2016b). Also the distance from the HEMS base to the site of injury has been reported as having an impact on trauma mortality (Rhinehart *et al.* 2013).

A large German study reported that trauma patients transported by HEMS had reduced mortality compared with those transported by road ambulances (Andruszkow *et al.* 2013). Mitchell *et al.* came to the same conclusion in their study done in Canada (Mitchell *et al.* 2007). The positive impacts of HEMS on survival in trauma have been demonstrated in several other studies (Abe *et al.* 2014, Andruszkow *et al.* 2013, Apodaca *et al.* 2013, Brown *et al.* 2010a, Brown *et al.*

2016a, Davis *et al.* 2005, Den Hartog *et al.* 2015, Desmettre *et al.* 2012, Giannakopoulos *et al.* 2013, Lossius *et al.* 2002, Newgard *et al.* 2010). There are, however, studies that have not been able to report any survival benefit of HEMS in trauma (Bulger *et al.* 2012, de Jongh *et al.* 2012, Iirola *et al.* 2006, Rose *et al.* 2012).

Some studies in the Nordic countries have investigated the impact of HEMS on outcome. In Finland, an expert panel evaluated the cost-benefits of HEMS and determined that they are at the same level with mammogram screening and dialysis treatment (Finnish Office for Health Care Technology Assessment 2000). The evaluation was based on a review of the literature and of material from two different HEMS bases in Finland. In another Nordic panel study, every 14th patient treated by pre-hospital anaesthesiologists was evaluated to calculate the number of life-years gained (Lossius *et al.* 2002). Of these, 19% were trauma patients. In another Norwegian study performed in a rural area, selected patient groups received considerable health benefits, but for most other patients, the benefit was small (Hotvedt *et al.* 1996). In Danish HEMS studies, the 30-day mortality of severely injured patients (Hesselfeldt *et al.* 2013) and the period of time trauma patients needed social transfer payments were reduced after implementation of HEMS (Funder *et al.* 2016, Hesselfeldt *et al.* 2013).

New pre-hospital equipment and procedures, such as point-of-care ultrasound, freeze-dried plasma and fresh red blood cells, resuscitative endovascular balloon occlusion of the aorta and pre-hospital thoracotomy, have been implemented in different services (Davies & Lockey 2011, Gellerfors *et al.* 2016, Nelson *et al.* 2011a, Nelson *et al.* 2011b). These factors should be taken into account when interpreting future studies of HEMS. The implementation of new therapies takes time and resources. The Utstein formula of survival used in resuscitation may be transferable to pre-hospital trauma, as well (Soreide *et al.* 2013). Education and training of EMS providers takes time, especially in EMS in rural area with long distances.

Aside from the impact of HEMS on survival, the costs and safety of HEMS are continuously debated (Finnish Office for Health Care Technology Assessment 2000, Taylor *et al.* 2013). Overuse of HEMS in the transport of trauma patients has been reported (Bledsoe 2003, Rose *et al.* 2012, Taylor *et al.* 2013, Vercruysse *et al.* 2015).

Use of advanced observational research methods such as propensity scoring and precision of logistic regression models is recommended in HEMS studies (Galvagno *et al.* 2013).

System factors that should be kept in mind when interpreting HEMS studies are, for example, the competence level of HEMS, dispatch criteria and the location of landing sites in trauma hospitals (Kruger *et al.* 2011, Lerner & Billittier 2000). A consensus-based template for documenting and reporting in physician-staffed pre-hospital services has been developed and is believed to facilitate studies of HEMS (Kruger *et al.* 2011).

2.6 Role of airway management in pre-hospital trauma care

Pre-hospital airway management is considered one of the most important interventions in severely injured patients (Lockey *et al.* 2015). The most optimal method in pre-hospital airway management is debated and is dependent on the experience of the providers. The basic techniques for pre-hospital airway management are manual opening of the airway and bag-valve-mask (BVM) ventilation, while endotracheal intubation (ETI) and the insertion of a supraglottic airway device (SAD) are advanced techniques. Guidelines published by the Scandinavian Society of Anaesthesiology and Intensive Care Medicine (SSAI) state that pre-hospital ETI should be performed on trauma patients only by anaesthesiologists, while BVM ventilation and the trauma recovery position should be used by others (Berlac *et al.* 2008).

Reporting of several end-points has been recommended in studies of pre-hospital airway management: success rates, complications and problems in addition to survival status (Sollid *et al.* 2009).

More evidence of the impact of pre-hospital airway management on survival - especially of endotracheal intubation (ETI) - is needed, but the different kinds of design and outcome measures of airway studies is a limitation when the results of these studies are interpreted. A systematic literature review of pre-hospital ETI revealed that Utstein airway variables are infrequently recorded (Lossius *et al.* 2011).

Data reported in the studies of pre-hospital airway management should be conducted in a systematic way and the use of a consensus template has been encouraged (Lossius *et al.* 2011, Sollid *et al.* 2009).

2.6.1 Success rates in pre-hospital airway management

In several studies, pre-hospital ETI has been associated with a high failure and complications rate (Cobas *et al.* 2009, Dunford *et al.* 2003, Katz & Falk 2001, Lockey *et al.* 2015). On the contrary, high success rates in pre-hospital ETIs of trauma patients have been reported if performed by anaesthesiologist-staffed EMS units (Lockey *et al.* 2014, Rognas *et al.* 2013a, Sollid *et al.* 2010, Sunde *et al.* 2015). If the amount of exposure is high, however, and a standard operating procedure is used, a high success rates in ETI has also been reported for specially trained paramedics (McQueen *et al.* 2015a). Supervision by an anaesthesiologist in emergency intubations has been reported to reduce complications (Schmidt *et al.* 2008).

High success rates in the use of SAD by EMS providers have been reported in several studies (Deakin *et al.* 2005, Lankimaki *et al.* 2013, Lankimaki *et al.* 2015). However, problems in relation to SAD use during cardiopulmonary resuscitation (CPR) have also been reported (Sunde *et al.* 2012). The pre-hospital use of SAD in other emergencies than cardiac arrest have reported to be promising (Bosch *et al.* 2014, Lankimaki *et al.* 2015, Schalk *et al.* 2010) but evidence is still limited. Specifically, SAD can be used successfully as a rescue airway when ETI has failed (Deakin *et al.* 2005, Sunde *et al.* 2015).

2.6.2 Impact on outcome

Evidence of the impact of pre-hospital ETI on outcome is limited (Lecky *et al.* 2008). In TBI patients, PHAAM has been suggested to be especially important (Sollid *et al.* 2008) and to have a positive impact on survival if performed by experienced pre-hospital providers (Bernard *et al.* 2010, Bossers *et al.* 2015, Davis *et al.* 2005, Davis *et al.* 2010, Hoffmann *et al.* 2016, Klemen & Grmec 2006, Pakkanen *et al.* 2016, Suominen *et al.* 2000). Furthermore, favourable functional outcomes of TBI patients have been reported in a RCT (Bernard *et al.* 2010).

But there are studies that have reported worse outcomes for patients intubated in a pre-hospital setting compared with those who were not intubated (Bochicchio *et al.* 2003, Davis *et al.* 2003, Davis *et al.* 2004, Gausche *et al.* 2000, von Elm *et al.* 2009, Wang *et al.* 2004).

The heterogeneity of the studies is a challenge when comparing the results (Lossius *et al.* 2011). The expertise of the EMS providers and other system variables should be reported in studies of pre-hospital airway management. (Sollid *et al.* 2009). There are differences in airway management protocols even between hospital districts in the same geographical region (Pakkanen *et al.* 2016).

2.6.3 Other factors in pre-hospital airway management

In addition to the importance of high success rates in pre-hospital ETIs, avoiding hyperventilation, hypoxia and hypotension are all important factors, especially for TBI patients (Badjatia *et al.* 2008, Stiver & Manley 2008). Hypotension and hypoxia have been reported to be common in TBI patients and are associated with secondary brain injury (Chesnut *et al.* 1993). Even in anaesthesiologist-staffed EMS units, hyperventilation and hypotension after intubation have been reported to be common (Rognas *et al.* 2014).

As well as pre-hospital airway management in itself, the decision to refrain from PHAAM is also an important point. These types of cases are, for example, those where it is better to perform PHAAM in-hospital, taking into account the patient's clinical situation and the skills of the EMS providers. Co-morbidity is shown to be the most common reason for refraining from ETI in anaesthesiologist-staffed units (Rognas *et al.* 2013b).

2.6.4 Airway management skills

Another important task in pre-hospital airway management is how to train and maintain skills in PHAAM. It takes time to gain experience and good success rates in ETI, and supervision by a senior is important due to complications during the learning process (Bernhard *et al.* 2012). It has been reported that approximately 50 ETIs on elective surgical patients in the operation room are required to achieve a success rate of at least 90% (Buis *et al.* 2016, Konrad *et al.* 1998, Mulcaster *et al.* 2003). The incidence of difficult airway management in emergencies has been reported to be 20 times higher compared with elective patients (Cook & MacDougall-Davis 2012).

Contrary to ETI, SAD has been shown to be easy to learn (Goliasch *et al.* 2013, Kurola *et al.* 2005, Lankimaki *et al.* 2013, Ruetzler *et al.* 2011, Tiah *et al.* 2005). Kurola *et al.* reported that inexperienced EMS non-paramedics had a 100% success rate in inserting a laryngeal tube for anaesthetised patients (Kurola *et al.* 2005). Skills in SAD insertion have also been reported to last longer when compared with ETI (Ruetzler *et al.* 2011, Tiah *et al.* 2005).

The challenge of maintaining skills in PHAAM has been reported to also be problematic for pre-hospital anaesthesiologists. In a semi-structured questionnaire done in western Norway, HEMS physicians felt they had insufficient exposure to

ETI, and nearly one-third reported that they were not familiar with backup airway devices in their system (Sollid *et al.* 2008).

2.7 Scores used in pre-hospital emergency care and trauma

Different kinds of scores are used in emergency medicine and their general purpose is to grade the severity of the patient's condition, measure treatment and diagnostics or forecast the prognosis. Some of the scores support clinical decision-making in therapy and triage (Schuster & Dick 1994).

In some services, the NACA score is used to measure overall severity of illness or injury in pre-hospital EMS (Weiss *et al.* 2001, Zakariassen *et al.* 2015).

The Mainz Emergency Evaluation Score (MEES) is a pre-hospital score that aims to evaluate the efficacy and quality of pre-hospital care (Hennes *et al.* 1993, Schuster & Dick 1994). Parameters used in the MEES are the Glasgow Coma Scale (GCS), heart rate, respiratory rate, cardiac rhythm, pain, blood pressure and oxygen saturation. Scoring is performed on-scene and in the emergency department. In trauma patients, combining capnometry with the MEES could improve its ability to predict outcome, despite the fact that the MEES is not intended for predicting prognosis (Grmec *et al.* 2007).

In Finland, four levels (A–D) of dispatch priority codes are used by the emergency medical communication centre, where A is most urgent (Lindstrom *et al.* 2011a). The same codes are used as transportation codes in EMS, based then on a subjective evaluation by EMS providers.

A simplified pre-hospital medical emergency team score has also been shown to correlate with hospital mortality and need for ICU treatment. (Jokela *et al.* 2015).

2.7.1 NACA score

The NACA score is a severity score used in a pre-hospital setting. It grades the severity of illness or injury from 0 to 7. Zero is no disease or injury and seven is pre-hospital death. (Table 1)

Table 1. National Committee on Aeronautics (NACA) score used in Norwegian Air Ambulance Services.

Score	Status
NACA 0	No injury or illness
NACA 1	Injuries/diseases without any need for acute physician care
NACA 2	Injuries/diseases requiring examination and therapy by a physician but hospital admission is not indicated
NACA 3	Injuries/diseases without acute threat to life but requiring hospital admission
NACA 4	Injuries/diseases which can possibly lead to deterioration of vital signs
NACA 5	Injuries/diseases with acute threat to life
NACA 6	Injuries/diseases transported after successful resuscitation of vital signs
NACA 7	Lethal injuries or diseases (with or without resuscitation attempts), pre-hospital death

The NACA score was first used to measure the severity of trauma 24 hours after admission (Statistisches Bundesamt Wiesbaden. 1968). After modification by Tryba et al., the NACA score now includes trauma and non-trauma cases at the time of handover from the EMS to hospital staff (Tryba *et al.* 1980).

Previous studies of the NACA score have investigated its ability to predict severity (mortality) and subjective factors in scoring.

It has been shown that the NACA score can be used to predict outcome, indicate the need of ICU admission and evaluate patient demographics in a pre-hospital setting (Bonatti *et al.* 1995, Weiss *et al.* 2001). Bernhard *et al.* prospectively studied how EMS physicians evaluated the severity of emergencies with the NACA score and need for admission (Bernhard *et al.* 2014). A higher NACA score predicted higher mortality and longer hospital stay, but significant differences were only found between NACA scores 5 and 6.

The NACA score has been criticised because of its sensitivity to subjectivity factors (Schlechtriemen *et al.* 2005a). Alessandrini *et al.* demonstrated that NACA score values are dependent on the pre-hospital phase of the disease or injury. For example, hypoglycaemia treated by intravenous glucose will be scored lower if status after the treatment is taken into account (Alessandrini *et al.* 2012). Knapp *et al.* studied the use of the NACA score in relation to the experience of the physician and found that less experienced physicians scored lower NACA scores than more experienced physicians (Knapp *et al.* 2008). To reduce the role of subjective factors, a modification of the NACA score called the Munich NACA score, which takes into account objective parameters such as GCS and respiratory rate, has been developed (Schlechtriemen *et al.* 2005b).

Despite the limitations due to the NACA score's subjectivity, it is widely used in the literature to describe the severity of emergencies (Afzali *et al.* 2013, Dami *et al.* 2015, Hasler *et al.* 2012, Zakariassen *et al.* 2015). For example, in a recently published study the NACA score was used to assess the accuracy of a Criteria-Based Dispatch (CBD) system (Dami *et al.* 2015). In that study, NACA scores > 3 were considered emergencies.

2.7.2 Abbreviated Injury Scale (AIS), Injury Severity Score (ISS) and New Injury Severity Score (NISS)

The Abbreviated Injury Scale (AIS) is an anatomic injury classification (Association for the Advancement of Automotive Medicine 2005). Each injury is ranked from 1 (minor) to 6 (un-survivable). When calculating the Injury Severity Score (ISS) each injury is allocated to one of the following body regions: head, face, chest, abdomen, extremities including also the pelvis and external structure. The maximum AIS score of the three most injured body regions is used in calculating the ISS (Baker *et al.* 1974). The AIS is felt to be superior compared with the International Classification of Diseases (ICD) in describing threat to life from anatomical injuries (Lecky *et al.* 2014).

The New Injury Severity Score (NISS) is a modification of the ISS. It takes into account the patient's three most severe injuries regardless of boy region. It has been shown to have better predictive value than the ISS (Osler *et al.* 1997). The NISS has also been shown to be more accurate in patients with head injuries (Eid & Abu-Zidan 2015, Lavoie *et al.* 2004, Lavoie *et al.* 2005) and is recommended to be used in studies of major trauma (Ringdal *et al.* 2008).

The definition of major trauma is commonly based on these anatomic scores, defined as an ISS or NISS > 15. There is, however, overall inconsistency regarding the definition of major trauma (Lossius *et al.* 2012a).

2.7.3 American Society of Anaesthesiologists Physical Status (ASA-PS)

One way to measure pre-injury comorbidity is the use of the American Society of Anaesthesiologists Physical Status (ASA-PS). It has demonstrated to be an independent predictor of mortality after trauma (Jones *et al.* 2014, Ringdal *et al.* 2013b, Skaga *et al.* 2007). ASA-PS is also included in the Utstein template for reporting of data following major trauma (Ringdal *et al.* 2008).

2.7.4 GCS, Revised Trauma Score (RTS) and Triage-Revised Trauma Score (T-RTS)

The GCS consist of visual, verbal and motoric responses. A pre-hospital GCS is a good predictor of outcome in trauma (Baxt & Moody 1987b, Davis *et al.* 2006). Changes between the GCS measured on the site of injury and in-hospital have been shown to correlate with mortality in patients with TBI (Davis *et al.* 2006). The motor component in the GCS appears to be most important predictor of outcome (Healey *et al.* 2003).

The RTS is a physiological trauma score used by trauma registries (Lecky *et al.* 2014). It consists of the coded measurements of GCS, systolic arterial pressure and respiratory rate (Champion 2002). Different components of the RTS have different types of weighting, with the GCS as the strongest weight. However, the RTS has become less used in clinical practice (Lecky *et al.* 2014).

A version of the RTS is the triage-revised trauma score (T-RTS), which is not weighted and is easier to calculate. It has been shown to have equal discrimination regarding mortality as the RTS (Moore *et al.* 2006). In some services, the RTS has been used for triage of trauma patients in a trauma centre.

2.8 Methods of measuring trauma outcome and trauma deaths

2.8.1 End points

Thirty-day mortality is recommended as an end point for reporting trauma mortality. The end of acute care as an end point is criticised because a relatively large proportion of deaths in blunt trauma occur after discharge from the hospital (Skaga *et al.* 2008). On the other hand, a substantial proportion of trauma deaths in LE falls occur later than 30 days after injury, so the true impact of LE trauma is often underestimated if 30-day mortality is used as an end point (Bakke *et al.* 2014).

Overall health impacts after major trauma are poorly described in the literature and most studies have used mortality as an outcome (Galvagno 2011, Hoffman *et al.* 2014). Health-related quality of life has been reported to be reduced long after severe injuries (Christensen *et al.* 2011, Livingston *et al.* 2009, Ulvik *et al.* 2008). Disability-adjusted life-years are internationally used to measure the consequences of fatal and non-fatal trauma. They combine the effects of mortality, morbidity and disability into a single measure (Haagsma *et al.* 2016, Polinder *et al.* 2012). The Glasgow Outcome Scale (GOS) is recommended for reporting outcome and recovery after trauma upon discharge from the main hospital (Ringdal *et al.* 2008). It is a five-scale score: death, persistent vegetative state, severe disability, moderate disability and good recovery (Jennett & Bond 1975).

EQ-5D has been recommended as an instrument for measuring quality of life after trauma (Derrett *et al.* 2009, Galvagno 2011) and it consists of the following dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression.

2.8.2 Trauma and Injury Severity Score (TRISS) methodology

Observed survival can be compared with the expected probability of survival to calculate standardised mortality ratios. In the TRISS method, probability is calculated by using the ISS, the RTS on admission, the mechanism of injury and the patient's age. Coefficients are derived from the Major Trauma Outcome Study (Champion *et al.* 1990b). The limitations for this method are missing RTS values and subjective factors in AIS scoring (Demetriades *et al.* 2001, Ringdal *et al.* 2008, Ringdal *et al.* 2013a). Therefore, other prediction models have also been developed and validated (Lefering 2012). Examples of these are the Norwegian Survival Prediction Model in Trauma (Jones *et al.* 2014), the Revised Injury Severity Classification (Lefering 2009, Lefering *et al.* 2014) and A Severity Characterization of Trauma (Champion *et al.* 1990a).

2.8.3 Peer-review panel

Expert panels have been used to evaluate whether a trauma death could have been prevented if optimal care had been delivered (Chiara *et al.* 2006). Normally, three categories of preventable deaths have been used: non-preventable, possibly preventable and definitely preventable death. Missing data, a case mix of the studied population and subjective factors have been considered limitations of the methodology (Chiara *et al.* 2006).

2.8.4 Autopsies

In general, autopsy findings have been used to compare clinical diagnoses. In studies that have compared clinical findings to autopsy findings, the proportions of discrepancies have varied between 6 and 32% (Combes *et al.* 2004, Goldman *et al.* 1983, Nadrous *et al.* 2003). The role of a post-mortem CT scan as an alternative to autopsy for trauma victims has been discussed but conclusions have not been drawn (Scholing *et al.* 2009).

3 Aims of the study

The general purpose of the studies was to obtain more data on severe injuries and EMS in pre-hospital trauma care.

The specific aims of the present work were

1. To study the crude incidence of fatal injuries in Northern Finland. (I)
2. To study the role of alcohol in fatal injuries in Northern Finland. (I)
3. To study rural-urban differences in injuries in Northern Finland. (I, II)
4. To compare the 30-day mortality and length of ICU stay of rural and urban trauma patients encountered by Finnish helicopter emergency medical services (FinnHEMS) units in Northern Finland. (II)
5. To assess the NACA score's ability to predict the 30-day mortality of trauma patients treated in rescue helicopter services. (III)
6. To study the frequency of occurrence, problems and skill maintenance in pre-hospital airway management by non-physicians in EMS in Northern Finland. (IV)

4 Material and methods

4.1 Definitions

4.1.1 Severely injured patients

Patients were defined as severely injured if their ISS was more than 15. (II)

4.1.2 Classification of rural and urban municipalities

Statistics Finland's classification divides municipalities into three categories (rural, semi-urban and urban) depending on their degree of urbanisation and rurality. (Table 2)

Table 2. Statistics Finland's grouping of municipalities.

Municipality type	Definition
Rural	- municipalities in which < 60% of the population lives in urban settlements and in which the population of the largest urban settlement is less than 15,000 - municipalities in which > 60% but less than 90% of the population lives in urban settlements and in which the population of the largest settlement is less than 4,000.
Semi-Urban	- municipalities in which 60% but less than 90% of the population lives in urban settlements and in which the population of the largest urban settlement is at least 4,000 but less than 15,000.
Urban	- municipalities in which at least 90% of the population lives in urban settlements or in which the population of the largest urban settlement is at least 15,000.

In the present study (I, II), rural and semi-urban municipalities were defined as rural and urban municipalities as urban.

4.1.3 Other definitions

Low-energy trauma was defined as a fall from lower than the person's height. (I, II) All other types of injuries were regarded as HE trauma. If the height was not determined, the fall was defined according the data available in death certificates. For example, if the fall had occurred on stairs but the exact height was undetermined, the fall was defined as high energy (HE) trauma. Burns, hypothermia and drowning were also classified as HE trauma.

The person was considered to be under the influence of alcohol if acute alcohol intoxication (ICD-10 X45, F10.0) was recorded in the cause of death register. (I) In Finland, screenings for alcohol and other substances are routinely performed during autopsy. Only pre-hospital deaths were included in the analysis of the influence of alcohol. (I)

HEMS response time was defined as the time from dispatch call to HEMS arrival on-scene. On-scene time was defined as HEMS arrival on-scene to time of transport start (II). Ventilatory support (III) was defined as institution or continuation of any form of positive pressure ventilation during the first 24 hours after admission. Non-invasive ventilation was also considered ventilatory support. Haemostatic emergency surgery was defined (III) as haemostatic packing of the abdomen or pelvis, or thoracotomy. In addition, a broader definition was also used that included tube thoracotomy and/or emergency orthopaedic procedures within 24 hours.

4.2 Study area

The population of Northern Finland—defined as Lapland, Northern and Central Ostrobothnia and Kainuu counties—was 728,847 inhabitants in 2010, with 56% of the population living in urban and 44% in rural and semi-urban municipalities. The area of Northern Finland comprises about 50% of the geographic area of Finland. (Fig 1).

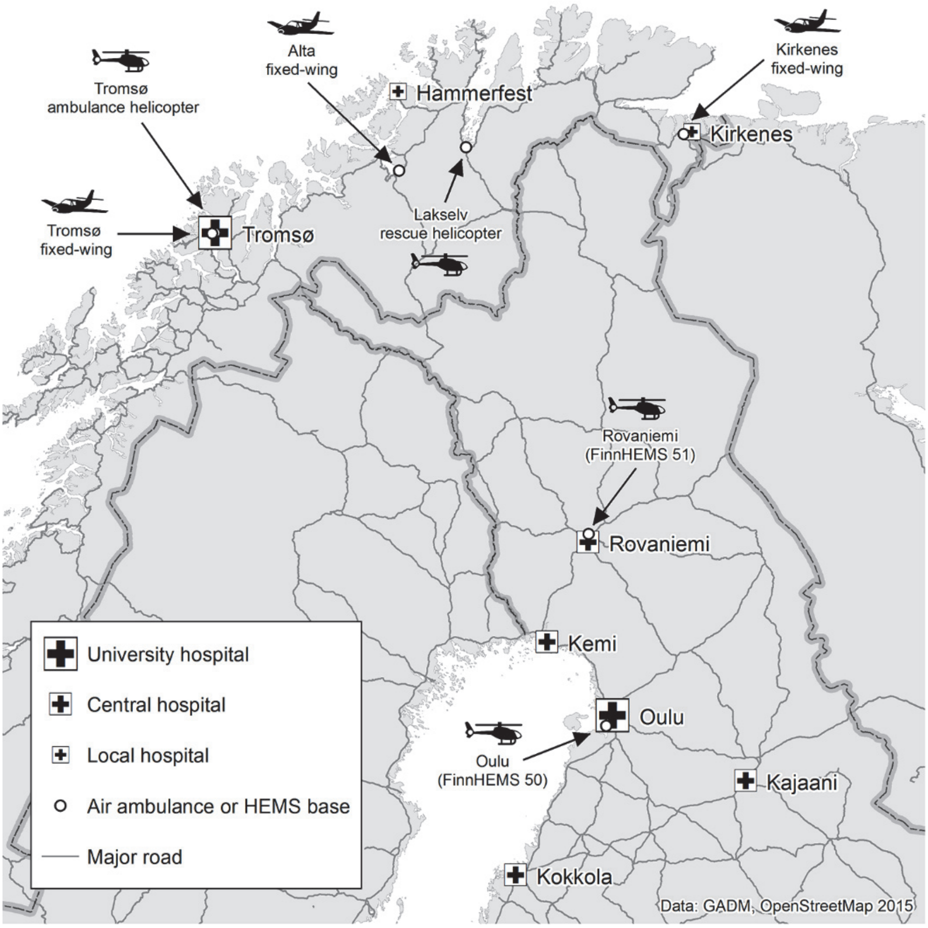

Fig. 1. Map of the study area. (I–IV).

4.2.1 EMS and trauma system in Northern Finland

In Finland, the dispatch centre receives emergency calls and dispatches units according to a national protocol. A HEMS unit is dispatched, if available, to all high-priority traumas and some medical conditions (Lindstrom *et al.* 2011b). Instructions in first aid are given to the caller, if needed.

Emergency medical response is tiered. Units of fire brigades normally have a function as a first responder. Basic- and advanced-level ambulances form the basis for EMS. The fourth tier of EMS is physician-staffed units (Langhelle *et al.* 2004).

Paramedic field supervisors have operational responsibility for ambulance resources (Norri-Sederholm *et al.* 2015) and they play a position as ambulance incident commanders during major incidents. Field commanders are experienced paramedics with special training in leadership in EMS and even in some advanced procedures such as ETI using sedative agents.

In Northern Finland, the Oulu University Hospital is the referral trauma centre, which has cardiac and neurosurgical care and invasive radiology. Lapland, Länsi-Pohja, Kainuu and Middle Ostrobothnia Central Hospitals are all able to perform emergency surgery other than cardiac or neurosurgery and have an ICU. According to local protocol, all multi-injured patients should be transported directly to the trauma centre in Oulu whenever possible.

FinnHEMS is a national company owned by all the university hospital districts and it is responsible for HEMS in Finland in cooperation with the university hospital districts. Northern Finland has two HEMS units. FinnHEMS 50 is anaesthesiologist-staffed HEMS operating out of Oulu and FinnHEMS 51 a paramedic-staffed HEMS operating from Rovaniemi. (Fig1) The FinnHEMS 51 paramedics use online consultation with the FinnHEMS 50 anaesthesiologist regarding treatment and transportation. Typical indications for consultations are ETI and sedation in emergencies, termination of CPR or transportation of a severely injured patient directly to the trauma centre in Oulu. Annually these units encounter together approximately 1,000 patients. The helicopter or a rapid-response car is used depending on the weather, the proximity of the mission to the HEMS base and/or other operational factors.

4.2.2 EMS and trauma system in Northern Norway

Despite EMS having many similarities in the Nordic countries, there are also differences and challenges in the different countries (Langhelle *et al.* 2004).
In Norway, ambulances are staffed primarily by EMS technicians that are allowed to administer intravenous medication such as thrombolysis after consultation with a physician. In Norway, contrary to Finland, general practitioners are involved in pre-hospital emergencies (Hjortdahl *et al.* 2014).

Medical dispatch centres are administered by hospital districts and dispatch calls are answered by nurses or ambulance coordinators.

The northernmost county in Norway, Finnmark, has one rescue helicopter base in Banak (Fig 1.), operated by the Norwegian Air Force (Haagensen *et al.* 2004). The helicopter is dispatched from a medical dispatch centre or a joint-rescue centre due to its own protocol and it is a part of Norwegian Air Ambulance services. Flying time to the site is longer in Banak than in the other bases in Norway (Zakariassen *et al.* 2015).

4.3 Finnish Cause of Death Registry (FCDR), death certificates and medicolegal autopsies

Statistics Finland is a statistical authority in Finland and administrates the FCDR. The coverage of the registry is 100 percent. Data of persons who have died in Finland or abroad during the calendar year and who at the time of death were registered residents of Finland are recorded in the FCDR. The cause of death statistics are based on death certificates and supplemented with and verified against data from the Population Information System of the Population Register Centre. If necessary due to deficiency, inconsistency or difficulty in coding the cause of death, the issuer of the death certificate or a medical expert is consulted. The death certificates and cause of death data have been shown to be of high quality (Lahti & Penttila 2001, Lahti & Penttila 2003).

The death certificate is issued by the physician establishing the death. The circumstances of death and a short history describing the examination and therapy are written in the death certificate. The physician sends the death certificate to the regional unit of the National Institute for Health and Welfare. A forensic pathologist verifies the correctness of the certificate and sends it to Statistics Finland. If an autopsy is required, the death certificate is issued by a forensic pathologist.

According to Finnish law, a medicolegal investigation must be conducted if death is caused or suspected to be caused by a crime, accident, suicide, poisoning, occupational disease or treatment. It has to be conducted also if death is unexpected, not caused by a disease or the victim has not been treated by a doctor during the last illness (Government of Finland 1973, Lunetta *et al.* 2007). The autopsy rate of trauma patients in Finland is high compared with many other countries in Europe (Lunetta *et al.* 2007, Pounder 2002).

4.4 FinnHEMS database

Since 2012, all HEMS missions have been recorded in a database in national HEMS. The data collected consists of the patient ID, mission data (location, time intervals) and patient characteristics including tentative diagnosis, mission type (trauma, medical, neurological, etc.), comorbidities, physiological parameters and patient management. In trauma patients the type of injury (blunt, penetrating) is also recorded.

4.5 Study permissions (I–IV)

The subjects and permissions for the studies are presented in Table 3.

Table 3. Study population.

Study	Design and subjects	Permissions
I	Retrospective analysis of fatal injuries that occurred in Northern Finland in 2007–2011. Fatalities (ICD-10 V01-Y89) identified from the Cause of Death Registry.	Regional ethics committee, Northern Ostrobothnia Hospital district 98/2013; the National Institute for Health and Welfare (THL/3/5.05.00/2014), the Regional State Administrative Agent of Northern Finland (PSAVI/2791/03.02.01/2014) and Statistics Finland (TK53-1151-13); Finnish Motor Insurers' Centre Traffic safety Committee of Insurance Companies, four hospital districts in Northern Finland
II	Retrospective study of trauma patients encountered by FinnHEMS 50 or FinnHEMS 51. Missions were identified from the HEMS database.	Regional ethics committee, Northern Ostrobothnia Hospital District 98/2013; Statistics Finland (TK53-1617-13); four hospital districts in Northern Finland
III	Retrospective study of all missions in 1999–2009 recorded with a NACA score in search and rescue helicopter Banak in Northern Norway	The Regional Committee for Medical and Health Research Ethics in Northern Norway (2010/3263-9)
IV	Cross-sectional survey of EMS providers (non-physicians) in Northern Finland	Regional ethics committee, Northern Ostrobothnia Hospital District 7/2012

4.6 Study I

4.6.1 Methods and outcomes

All deaths with an external cause of injury (tenth revision of Diseases and Related Health Problems, ICD-10 V00-Y89) between January 1, 2007 and December 31, 2011 were identified from the Cause of Death Registry (FCDR) and were included in the analysis. (Table 3) Exclusion criteria were: treatment-related death, poisonings other than those resulting from fire, deaths occurring > 90 days after injury, place of injury abroad or outside the study region and the municipality of injury not possible to determine.

The influence of alcohol was recorded only for patients that died pre-hospital because the definition of the influence of alcohol in-hospital may be unreliable. All who died in a pre-hospital setting were autopsied. If a trauma patient dies before arrival in-hospital in Finland, the case is not recorded as a hospital admission.

The primary outcome measure was the crude incidence of injuries leading to death in Northern Finland. Secondary outcome measures were the rural-urban differences in fatal injuries and the proportion of pre-hospital deaths under the influence of alcohol.

4.7 Study II

4.7.1 Methods and outcomes

All missions where FinnHEMS 50 or 51 encountered a patient and recorded the mission as resulting from trauma between January 1, 2012 and December 31, 2013 were identified from the electronic HEMS database. (Table 3) In addition, all trauma missions that were aborted due to pre-hospital death, declared by other units before HEMS arrival, were recorded from the database.

Only trauma cases where the patient survived to hospital were included in the analysis. Pre-hospital data consisted of the following information: pre-hospital times, pre-hospital therapy, transport method, escorted by FinnHEMS, use of a helicopter, location of the incident and HEMS unit involved,

In-hospital data were recorded from hospital records and the intensive care databases in each hospital. The main researcher (Lasse Raatiniemi), certified in AIS, performed the scoring. Data regarding 30-day mortality were obtained from the Causes of Death Registry, Statistics Finland.

Road and straight-line distances from the site of injury to the FinnHEMS base and receiving hospitals were calculated using ArcGIS 10.2 software (ESRI, Redlands, CA).

The primary outcome measure was the 30-day mortality of rural and urban trauma patients. The secondary outcome measure was the length of ICU stay and the study aimed also to describe the demographics, occurrence and acute care of trauma in HEMS in Northern Finland.

4.8 Study III

4.8.1 Methods and outcomes

The missions performed by The Royal Norwegian Air Force's anaesthesiologist-staffed search and rescue helicopter from January 1, 1999 to December 31, 2009 were reviewed. (Table 3) The missions where the anaesthesiologist encountered a patient and used a NACA score were included.

Electronic pre-hospital data records were used to retrieve all pre-hospital data. In-hospital data were recorded from the hospital records in Tromsoe, Hammerfest and Kirkenes. The hospital records are based on The National Population Register, which made it possible to assess 30-day mortality. Patients not residing in the study region (North Norway) were lost to follow-up regarding 30-day mortality if they were transferred to institutions outside the study region within 30 days after admission. If the patients were discharged home directly from the institution into which they were admitted, they were considered survivors.

Patients with a NACA score of 0 (no illness or injury) or 7 (pre-hospital death), patients transferred to institutions outside the study region and patients with incompletely recorded data or not recorded in electronic medical records were excluded.

The primary aim was to study the NACA score's relation to 30-day mortality and the NACA score's ability to predict the need for in-hospital interventions, respiratory therapy and haemostatic emergency surgery.

4.9 Study IV

4.9.1 Methods and outcomes

A structured questionnaire was sent to 383 EMS providers (non-physicians) in Lapland, Kainuu and Northern Ostrobothnia hospital districts during the first half of 2012. (Table 3) The questionnaire consisted of 30 questions regarding the equipment used, the frequency of cases and problems experienced previously in airway management. The questions followed a consensus-based template for reporting pre-hospital airway management (Sollid *et al.* 2009), whenever possible.

The aims of the study were to obtain baseline information on pre-hospital airway management performed by non-physicians in Northern Finland: frequency, equipment, maintaining and training in airway management. In addition, the study evaluated the current status of pre-hospital airway management in relation to SSAI guidelines for pre-hospital airway management.

4.10 Statistical analysis (I–IV)

The crude mortality rate of fatal injuries was expressed per 100,000 inhabitants, within a 95% confidence interval. (I) It was calculated for the entire study region and separately for rural and urban municipalities. The crude mortality rate was based on the municipality of residence of the victim. The year 2010 was the index year for the population and the structure of the municipalities in the region in this study. The study period of five years was estimated to be sufficient to reduce bias that could result from changes in the trauma system and other possible bias. (I)

Continuous variables were presented as medians and 25^{th}–75^{th} percentiles (I, II, III) or as averages with range. (IV) The Mann-Whitney test was used to compare continuous data and Pearson's chi-square test was used for categorical data. (I, II,)

A multivariate logistic regression model was used in study II. Only severely injured patients were included in the model. In it, two adjusting covariates were used at a time to assess the impact of the type of municipality on 30-day mortality. The following adjusting covariates were chosen: age, gender, ISS, the type of HEMS unit, distance to the site of injury, HEMS response times, on-scene times and transport times. The number of adjusting co-variates was based on the number of trauma deaths. The ISS and age were categorised. (II) The relationship between NACA score and 30-day mortality was assessed using receiver operating characteristics (ROC) curves. Area under the curve (AUC) > 0.8 was regarded as a good and > 0.95 as an excellent predictor for 30-day mortality. (III)

5 Results

The main results of the present study are presented in Table 4.

Table 4. Main results of the study.

Study	Aim	Subjects included the analysis	Main results
I	To study the incidence of fatal injuries, the influence of alcohol in pre-hospital deaths and rural vs. urban differences	1,959 out of 2,915 included in the analysis	High crude incidence of fatal injuries 1.5-fold incidence in rural areas The influence of alcohol was recorded in 42% of pre-hospital deaths
II	To study short-term outcome of trauma patients encountered by HEMS and to describe trauma care in HEMS	472 out of 558 patients included in the analysis	Severely injured patients in urban areas trend to higher 30-day mortality Length of ICU stay was similar in rural and urban patients Frequency of severe trauma was low/HEMS provider/year
III	To study the NACA score's ability to predict mortality and need for ventilatory support within 24 hours	1,533 out of 1,841 patients included in the analysis	The NACA score had good discrimination for 30-day mortality and the need for ventilatory support.
IV	To study the incidence and problems in airway management and how skills are maintained	226 out of 383 EMS non-physicians responded to the questionnaire; 224 valid responders	Low frequency for pre-hospital airway management 26% participated in anaesthesiologist-guided airway management during the past year High number of reported problems

5.1 Crude incidence of fatal injuries in Northern Finland (I)

A total of 2,915 deaths were retrieved and 1,959 of those met the inclusion criteria after exclusion of deaths resulting from treatment (n = 11), poisonings (n = 741), occurrence later than 90 days after injury (n = 118), fatal injuries that occurred abroad or outside the study area (n = 81) and deaths where the municipality of injury was not possible to determine (n = 5).

The causes of unintentional fatal injuries were: HE trauma 33% (644/1,959), LE trauma 31% (609/1,959), suicide 29% (569/1,959) and assault 4% (84/1,959). In 3% (53/1,959) the cause of injury was unknown.

The crude incidence of fatal injuries was 54 (95% CI 51–56) per 100,000/year. The majority, 73% (1,430/1,959), were males. The median age was 58 years (25^{th} to 75^{th} percentiles 43–79). Age was lowest in suicides, 47 years (30–59), and assaults, 43 years (28–55). The highest median age was in LE trauma, 82 years (69–88). The crude mortality rate was higher in rural municipalities than in urban municipalities.

The crude incidence of fatal injuries was 65 (95% CI 57–75) in rural and 45 (95% 42–48) in urban municipalities. The crude incidences of fatal injuries are shown in Table 5.

Table 5. Crude incidence of fatal injuries per 100,000 inhabitants per year, with 95% confidence intervals.

Mechanism	Northern Finland	Rural areas	Urban Areas
All mechanisms	54 (51–56)	65 (57–75)	45 (42–49)
Unintentional high-energy	18 (16–19)	23 (18–29)	14 (12–15)
Unintentional low-energy	17 (15–18)	21 (16–27)	13 (12–15)
Suicides	16 (14–17)	17 (13–22)	15 (13–16)
Unknown	2 (1–2)	2 (1–4)	1 (1–2)

An autopsy was performed in 90% (1,759/1,959) of the deaths. Rural fatalities had autopsy rate of 88 percent and urban, 92 percent. In pre-hospital deaths the autopsy rate was 100%.

5.2 Proportion of fatal injuries occurring in rural areas vs. population residing in rural areas (I)

More fatal injuries occurred in rural areas in relation to the population than in urban areas. In all, 47% of the fatal injuries (923/1,959) occurred in the population living in urban areas, but 45% of the fatal injuries occurred in urban areas. In the fatalities resulting from road traffic incidents, 46% (79/173) of the victims were urban residents but only 38% (66/173) of the injuries occurred in urban areas.

5.3 Proportion of pre-hospital deaths in fatal injuries in Northern Finland (I)

The majority (1,241/1,959, 66%) of deaths were pre-hospital. (I) In 88% (1,089/1,241) of the deaths that occurred on-scene, resuscitation was not attempted. One percent (11/1,241) of the patients who died on-scene still had documented signs of life after the arrival of EMS.

In HE trauma, 74% (479/644) of the deaths were pre-hospital and only 1% (7/644) died during transportation to hospital and 3% (21/644) in the emergency room (ER). In LE trauma, death occurred most often (33%, 200/609) during primary admission to hospital. In suicides the death was pre-hospital in 95% (542/569) and in assaults, in 90% (76/84) of the cases. The proportion of pre-hospital deaths during primary admission and later are shown in Table 6. Fifty-three percent (1,046/1,959) of the deaths occurred during the first hour after injury in all the material except LE trauma, where 53% (323/609) of the deaths occurred later than one week after injury. The time from injury to death could not be estimated in 4% (72/1,959) of the deaths.

Table 6. Place of death (pre-hospital, during primary admission, later) presented as numbers (%). Assaults and suicides are presented only in pre-hospital deaths due to the low number of deaths during admission or later.

Place of death	Total N = 1959	Rural area N = 1085	Urban N = 874
All deaths	1959 (100)	1085	874
Pre-hospital	1241 (63)	701 (65)	540 (62)
During admission	382 (20)	194 (18)	188 (22)
Later	336 (17)	190 (18)	146 (17)
Unintentional HE trauma	644 (100)	392	252
Pre-hospital	479 (74)	306 (78)	173 (69)
During admission	141 (22)	72 (18)	69 (27)
Later	24 (4)	14 (4)	10 (4)
Unintentional LE trauma	609 (100)	333	276
Pre-hospital	100 (16)	55 (17)	45 (16)
During admission	200 (33)	103 (31)	97 (35)
Later	309 (51)	175 (53)	134 (49)
Assaults	84 (100)	46	38
Pre-hospital	76 (91)	40 (87)	36 (95)
Suicides	568 (100)	285 (100)	283 (100)
Pre-hospital	542 (95)	275 (97)	267 (94)

5.4 Influence of alcohol in fatal injuries (I)

The influence of alcohol was recorded in 42% (515/1,241) of pre-hospital deaths. There was no difference between rural and urban municipalities. The influence of alcohol was most commonly recorded in assaults (50%, 38/76) and LE traumas (48%, 48/100). The influence of alcohol was documented in 41% (198/479) of HE traumas and 37% (200/542) of suicides.

5.5 Place of fatal injury (I)

The most common place of fatal HE trauma was on roads (34%, 221/644) and in residential areas (33%, 214/644). In fatal LE traumas the most common places of injuries were residential areas 52% (314/609) and hospitals or nursing homes 37% (225/609). Residential areas were also the most common places of fatal injuries in suicides (68%, 388/569) and assaults (74%, 62/84).

5.6 Month and weekday in pre-hospital deaths (I)

The rate of deaths in the different months varied from 7% (85/1,241) in September to 11% (141/1,241) in June.

The rates of deaths on the different weekdays varied from 13% (156/1,241) on Thursdays to 18% (222/1,241) on Saturdays.

5.7 Trauma patients treated by HEMS in Northern Finland (II)

A total of 558 trauma patients were encountered by FinnHEMS. This accounted for 29% of all patients encountered by FinnHEMS 50 and 51 during the study period. Twenty patients died pre-hospital. Patients with an unknown personal ID (n = 22), not admitted to a hospital (n = 35), trauma occurred more than 24 hours ago (n = 2), no indication of trauma at all, for example cerebral insult or poisoning (n = 5), and pre-hospital death (n = 20), as well as inter-hospital transfer missions (n = 2) were excluded. Finally, a total of 472 patients met the inclusion criteria. Of these, 33% (156/472) had severe injuries.

5.7.1 Patient demographics

The majority, 70% (330/472), of the trauma patients were male. Median age was 33 (25^{th} to 75^{th} percentiles 20–55). Median ISS was 9 (3–17). Blunt injuries comprised 86% (408/472) of all injuries. In all, 92% (436/472) of the patients had no or only minor comorbidities, measured by ASA-PS (ASA-PS I and II). (II)

5.7.2 Rural-urban differences

Fifty-three percent (249/472) of all the trauma patients and 55% (85/156) of the severely injured were injured in rural municipalities. Patients injured in rural areas more often had unintentional injuries than patients injured in urban areas (90% vs. 74%, $p < 0.001$). On the contrary, there were more assaults in urban than rural areas (14% vs. 5%, $p < 0.001$). Age, ASA-PS, ISS and dominant type of injury did not differ between rural and urban patients.

Median air distance from the site of injury to the receiving hospital was 112 (67–144) km in rural and 6 (3–20) km in urban municipalities. HEMS response time was 39 (28–53) and 11 (8–18) minutes. On-scene time was longer in rural municipalities (22 vs. 15 minutes, $p < 0.001$).

5.7.3 Use of a helicopter and transportation

A helicopter was used in 53% (242/472) of the missions. A helicopter was used more often in rural than urban areas (80 vs. 20%, $p < 0.001$).

Of the severely injured patients, 79% (123/156) were directly transported to the university hospital from the scene. The proportion of patients first transported to the central hospital and later transferred to the university hospital was 12% (19/156). Nine percent (14/156) of the severely injured patients were only admitted to the central hospital. Twenty-one percent (33/156) of the severely injured patients and 21% (100/472) of all the trauma patients were transported by helicopter.

5.8 Thirty-day mortality of trauma patients encountered by FinnHEMS 50 and 51 (II)

All the trauma patients who died after admission to hospital had an ISS > 15. Three patients were lost to follow-up (transferred abroad). Thirty-day mortality was 18% (28/154) for all severely injured together and 13% (11/83) for rural and 24% (17/71) for urban patients ($p=0.09$).

In multivariate logistic regression analysis for 30-day mortality, the best model was built using the ISS and age as adjusting covariates. The odds ratio for urban municipality was 2.8 (95% CI 1 to 8, $p = 0.05$)

Nineteen patients died on-scene and cardiopulmonary resuscitation (CPR) was attempted for three patients. One died during transportation. Of these 20 patients, 16 were from urban scenes.

The HEMS mission was cancelled due to pre-hospital trauma death declared by other units on-scene in 56 cases. Of these missions, 73% (41/56) were in rural municipalities. More detailed information on cancelled missions was not recorded in the HEMS database. One mission may contain more than one trauma death.

5.9 Length of intensive care stay of trauma patients treated by HEMS (II)

A total of 40% (190/472) of trauma patients were admitted to an ICU. Of these, 188 were included in the mortality analysis. The 30-day mortality of the patients treated in an ICU was 14% (12/85) in the urban group and 9% (9/103) in the rural group ($P = 0.24$). There were no differences in ICU LOS, severity of illness scores or need for respiratory therapy between the rural and urban patients.

5.10 NACA score and mortality in a cohort from Northern Norway (III)

A total of 1,841 patients with a NACA score were recorded during the study period. Of these, 1,533 met the inclusion criteria after exclusion of patients with a NACA score of 0 (n = 16) or 7 (n = 122). In all, 170 patients were lost to follow-up: 35 patients were transferred to other hospitals outside the study region, 118 patients had incompletely recorded data that made mortality analysis impossible and 17 patients were not recorded in electronic medical records at all.

A total of 625 (41%) patients were trauma patients. The median age in trauma cases was 34 years (20–50), and 50 years (32–66) in non-trauma cases. Males comprised 75% of trauma and 60% of non-trauma cases.

The overall 30-day mortality was 5% (79/1,533). Non-trauma patients' 30-day mortality was 7% (67/908) and that of trauma patients 2% (12/625). This difference was statistically significant ($p < 0.0001$).

The NACA score's ability to predict 30-day mortality was excellent for trauma patients (AUC = 0.98, 95% CI 0.97–1.00) and good for non-trauma patients (AUC = 0.86, 95% CI 0.76–0.88) and for the overall study material (AUC = 0.82, 95% CI 0.81–0.91).

A total of 9% (137/1,533) of the patients received ventilatory support within 24 hours after admission to hospital. Of these, 34% (47/137) were trauma patients. The NACA score's ability to predict the need for ventilatory support was excellent for trauma patients (AUC = 0.94, 95% CI 0.90–0.97) and good for non-trauma patients (AUC = 0.82, 95% CI 0.76–0.88).

Haemostatic emergency surgery, defined as packing of the abdomen or pelvis, was performed for five patients and the AUC was 0.94 (95% CI 0.87–1.0). When a broader definition for emergency surgery (n = 36) was used, the AUC was 0.76 (95% CI 0.68–0.85).

5.11 Equipment, incidence and problems in airway management by non-physicians (IV)

A questionnaire was send to 383 EMS providers and 224 valid answers were included in the analysis, leading to a response rate of 59%.

The majority of the respondents replied that they have a SAD as well as capnography available (90% and 95%), and one-third had equipment for mechanical ventilation.

Most of the respondents (83%, 185/224) were allowed to perform advanced airway management pre-hospital. The annual mean pre-hospital ETI frequency was two per EMS provider (range 0–16, n = 185). Thirteen percent (24/185) of these had performed more than five ETIs and 38% (71/185) had not performed ETI at all during the last year. EMS providers working in the most remote ambulance stations (> 60 minutes to the nearest hospital) had the lowest ETI frequency (1, range 0–15), and those working in stations located near the hospital had the highest (3, range 0–16).

When asked about problems experienced during their career regarding pre-hospital ETI, 66% (119/181) reported having experienced an unsuccessful ETI and 81% (147/181) a difficult ETI. A misplaced tube in the oesophagus had been experienced by 52% (89/170) of EMS providers.

5.12 Training in airway management (IV)

Airway management training with a manikin had been implemented by 81% (182/224) of the EMS providers and 26% (56/224) had trained for airway management (ETI, SAD or BVMV) in an operating room (OR) during the last 12 months. Of those who had received anaesthesiologist-guided training, 88% (49/56) had performed ETI and only 42% (23/56) had inserted a SAD in an OR. Participation in airway management-related simulation training was reported by 64% (143/223) of the respondents.

When asked how many ETIs and SAD insertions they would need to perform during a 12-month period to be able to maintain their skills adequately, the answers were, on average, 17 ETIs and 10 SAD insertions in an OR or an emergency care setting.

6 Discussion

6.1 Main findings

The results of this study confirm a high incidence (65 deaths per 100,000 inhabitants per year) of fatal injuries in the rural areas which also holds true in Northern Finland. (I) If the trauma patients survived to be treated by HEMS, the possibility of survival of rural trauma patients was good in both Northern Finland and Northern Norway. (II, III)

The majority of the deaths were pre-hospital and a large proportion of rural trauma patients died before the arrival of EMS or FinnHEMS. (I,II) Alcohol use prior to injury was documented in a substantial proportion of the fatalities. The proportion of suicides was high; nearly all suicide victims were found dead. (I) Advanced airway management was not regularly practiced in a pre-hospital setting by non-physicians. (IV) Also, the number of severely injured patients encountered per anaesthesiologist or paramedic in HEMS per year was low. (II)

Reporting of patient demographics in HEMS is important, and the NACA score is a simple severity score and correlated well with short-term outcome. (III) It can be used to describe the overall severity of patient demographics in HEMS on regional, national and international levels.

6.2 Fatal injuries in Northern Finland (I, II)

The findings of the present study (I) are in concordance with other studies reporting the high crude incidence of fatal injuries and the proportion of pre-hospital deaths in rural areas (Bakke & Wisborg 2011, Bakke *et al.* 2013, Evans *et al.* 2010, Fatovich & Jacobs 2009, Fatovich *et al.* 2011b, Gomez *et al.* 2010, Grossman *et al.* 1997, Kristiansen *et al.* 2012a, Kristiansen *et al.* 2014).

The explanation for the higher incidence of fatal injuries in rural areas is multi-factorial (Peek-Asa *et al.* 2004, Simons *et al.* 2010). The total number of injuries with different mechanisms remains unknown, and no conclusions on whether rural injuries are more common or have a different kind of severity can be drawn from the present study. Traffic incidents alone do not explain the difference in the incidence of fatalities between rural and urban areas in the present study. The crude incidence of fatal injuries was higher in rural areas with all mechanisms. The majority of the deaths occurred within one hour after injury and it is likely that patients injured in urban areas more often survived to hospital. (I, II) This can partly explain why rural areas had a higher share of pre-hospital deaths.

6.3 Influence of alcohol in fatal injuries in Northern Finland (I)

Forty-two percent of pre-hospital trauma deaths occurred under the influence of alcohol. The finding in the present study is higher compared with previous studies, which have reported a less than 25% pre-injury alcohol intake (Ahlner *et al.* 2014, Jones *et al.* 2009). Regarding suicides, our findings are similar to Holmgren et al., who reported that 34% of the victims had consumed alcohol before death. (Holmgren & Jones 2010).

In the present study, 48% of those who died pre-hospital after LE trauma were influenced by alcohol. This is in line with the studies that have reported that alcohol is a risk factor for fall injuries (Friedland *et al.* 2014, Puljula *et al.* 2013).

As alcohol is an independent risk factor for injury, programmes that aim to reduce alcohol consumption are important. Especially those patients admitted to the trauma centre with a high blood alcohol concentration have been reported to be risk users of alcohol and tend to be re-admitted to the trauma centre again during follow-up (Afshar *et al.* 2016).

In the present study, we were not able to find any difference between rural and urban areas regarding the influence of alcohol in pre-hospital deaths, which emphasises that the prevention of alcohol abuse should be targeted to both rural and urban populations.

6.4 Mortality and morbidity of trauma patients in HEMS (II)

There was a trend towards a higher 30-day mortality in patients injured in urban areas compared with patients injured in rural areas. (II) A large proportion of trauma deaths occurred before the arrival of HEMS or other health care providers, and the number of these kinds of missions was higher in rural areas. (I, II) This is in concordance with previous studies reporting that a high proportion of rural trauma patients die before the arrival of EMS (Fatovich *et al.* 2011b, Rogers *et al.* 1997).

Differences in outcomes of trauma patients treated by HEMS units have not been widely studied in the rural-urban context. McCowan *et al.* studied in-hospital mortality of patients with blunt trauma injured in both rural and urban areas (McCowan *et al.* 2007). Despite longer pre-hospital time for the rural patients, in-hospital mortality was similar. In contrast, another study reported higher hospital mortality for paediatric trauma patients injured in urban areas (McCowan *et al.* 2008). Contrary to the present study, two Swedish studies have reported a higher 30-day mortality for trauma patients with long pre-hospital times (Brattstrom *et al.* 2010, Henriksson *et al.* 2001). When interpreting the impact of pre-hospital time on the study of Brattström et al, it should be kept in mind that in the urban Stockholm area, the pre-hospital anaesthesiologist is available only during the day-time (Ghorbani *et al.* 2016).

In the present study, the high number of trauma deaths occurred within an hour from the event, indicating that very seriously injured patients may survive to hospital in urban areas with short pre-hospital times, contrary to rural patients, who may have died on-scene or during transportation. (I, II) This is in line with a recently published study, according to which patients with shorter pre-hospital times had higher mortality rates in the ER (Byrne *et al.* 2016). The higher ER mortality of patients with shorter pre-hospital times most likely resulted from the fact that the patients more often had penetrating injuries and were injured in urban areas. In concurrence with this, a Norwegian study investigating transferred trauma patients found a higher mortality in patients transferred to the trauma centre from shorter distances (Kristiansen *et al.* 2011). The authors concluded that this may reflect the different phases of care.

The present study did not aim to evaluate the impact of HEMS by itself on survival. It can be said, however, that if the trauma patient survived to hospital by FinnHEMS, there was no statistically significant difference in 30-day mortality or ICU stays and scores between rural and urban patients. Factors such as notification of an incident, dispatch, bystander first aid and the level of care given by ground EMS are all factors that play an important role before the arrival of HEMS if the patient is survivable at all.

When comparing the results of different types of HEMS, the differences between services should be kept in mind. For example, in the studies from North America, physicians do not routinely participate in primary missions. On the contrary, physician-staffed HEMS in the Nordic countries have many operational and organisational similarities (Kruger *et al.* 2010). On the other hand, not all HEMS units are staffed by physicians (Ghorbani *et al.* 2016).

6.5 Frequency of severe injuries in HEMS in Northern Finland (II)

During the study period, 156 of the trauma patients encountered survived to hospital and 20 died before hospital. With this frequency, both FinnHEMS units together encountered 1.7 severely injured patients every week; about two-thirds of these by pre-hospital anaesthesiologists. This means that the annual frequency of treating severely injured trauma patients in a pre-hospital environment is low per HEMS provider. On the other hand, it is likely that HEMS providers encounter severe trauma patients more often than paramedics working in ground ambulances, which operate in narrower geographical area than HEMS units.

Low frequencies of medical procedures by HEMS physicians have been reported by others as well (Gries *et al.* 2006, Gries *et al.* 2006, Sollid *et al.* 2008, Sollid *et al.* 2015). For example, the rate of ETI of trauma patients was calculated as 0.8 to 5 times per year per physician, depending on the activity of the base (Sollid *et al.* 2015).

Maintaining trauma management skills requires regular training. Simulation training and periodic practicing in hospitals and large trauma centres with a higher incidence of severe injuries than in the Nordic countries could compensate for the low frequency of severe trauma in HEMS in our region. For example, scenario-based simulation training in HEMS using simple mannequins or student volunteers has been found to be a useful method (Bredmose *et al.* 2010). As the volume of severely injured patients is low in HEMS, it takes time to acquire cumulative experience in pre-hospital trauma care. With this in mind, the turnover of EMS providers should be kept at a minimum in HEMS, and the beginners should especially receive regular feedback about the missions. Low procedural frequency in trauma, such as ETI, may be compensated by the fact that HEMS is also used in types of emergencies other than trauma.

Only a minority of trauma patients were transported by helicopter. On the other hand, a rapid response vehicle was frequently used. Therefore, a more appropriate term for HEMS units would be FinnHEMS emergency critical care units.

6.6 NACA score in predicting 30-day mortality (III)

In the present study, conducted in a single rescue helicopter base in a rural area in Northern Norway, the NACA score reliably predicted 30-day mortality in trauma patients. The results in the present study are similar to previous studies of the NACA score and mortality (Bonatti *et al.* 1995, Weiss *et al.* 2001). Overall mortality in the present study was lower than that observed by others. The most likely reasons are the low number of severely injured patients in the present study and a different kind of patient demographic.

According to observations in the present study, mortality with a NACA score of 5 was similar to the finding in the study by Bonatti and Weiss, but mortality with a NACA score of 6 was lower. This may be a result of the long pre-hospital times and the fact that a large proportion of deaths occurred in a pre-hospital setting before the arrival of EMS (Bakke & Wisborg 2011, Wisborg *et al.* 2003).

Despite the limitations of the NACA score, such as subjective factors, it is a simple and widely used score that makes comparison of the severity of patient demographics possible. It is important to be able to measure the severity of the missions for several reasons, such as the possibility to compare workload in different bases or for research purposes. If used for these purposes, the same timing for scoring should be used (Alessandrini *et al.* 2012) and the scoring should be based on the pre-hospital status of the patients, not on findings in-hospital.

The NACA score in the present material proved to have a high negative predictive value and a low positive predictive value. This might have resulted from the low overall mortality rate in the material. The NACA score should not be used as triage tool, as a low NACA score does not necessarily exclude serious injuries or other life-threatening situations.

In the present study material, the maximum NACA score in the worst clinical condition was used. While the pre-hospital times were long, the clinical situation of the patients was also observed for a lengthy period of time in the pre-hospital setting. It is likely that this improved the reliability of the scoring performed by experienced anaesthesiologists.

6.7 Airway management by non-physicians in Northern Finland (IV)

In the present study, pre-hospital drug-assisted ETI was widely performed by non-physicians with very little clinical exposure to PHAAM, despite it being recommended as a procedure to be performed only by selected EMS providers or anaesthesiologists in trauma (Berlac *et al.* 2008, Deakin *et al.* 2010, Sollid *et al.* 2008). Moreover, the overall frequency of performing PHAAM was low in the present study. Accordingly, the maintenance of skills was insufficient.

The present findings correspond closely with previous studies of procedural frequency in pre-hospital care (Burton *et al.* 2003, Deakin *et al.* 2009, Wang *et al.* 2005). Based on the findings in the present study, drug-assisted intubation cannot be recommended. In general, airway management in emergencies is a challenge even for physicians working in-hospital: the incidence of difficult ETIs and complications is high (Martin *et al.* 2011). In a pre-hospital setting, in addition to an in-hospital environment, there are factors which may make airway management even more challenging: resources, competence, environmental factors (weather, safety aspects) and data lacking from the patient's medical history, including information as to a previous difficult ETI.

Despite a SAD being easier to use and learn (Kurola *et al.* 2005, Lankimaki *et al.* 2013), ETI was the most commonly used method for airway management in the present study. The possible reasons for this may result from the tradition of using ETI as the primary method and the fact that SAD insertion is not routinely practised during anaesthesiologist-guided OR training. A recently published Finnish study reported that ETI success rates were higher compared with SAD insertion success rates during CPR (Hiltunen *et al.* 2016). The authors concluded that additional training in SAD use is indicated for BLS providers.

Training in the OR has its limitations due to medico-legal reasons. On the other hand, SAD use has replaced ETI in many operations (Johnston *et al.* 2006). Due to these reasons, OR training is not a realistic option for gaining a sufficient number of ETIs for all EMS providers in Northern Finland.

EMS providers reported that they would need in average higher number of ETIs or SAD insertions yearly than they actually performed in the pre-hospital setting in order to be able to maintain their skills in airway management. This can be interpreted that clinical exposure is not sufficient to justify pre-hospital ETI. According to the present results, PHAAM in trauma performed by anaesthesiologists or specially trained paramedics with sufficient training in wide geographical areas with a sparse population and a low frequency of events is only possible by means of HEMS.

The present study showed that airway management skills and procedures need to be improved in Northern Finland. In this context, it should be kept in mind that PHAAM is not just successful intubation or insertion of a SAD. There are several factors that should be taken into account when implementing the revised procedures in pre-hospital airway management in EMS. First, airway management should be safe and the providers should have sufficient experience. Second, securing adequate training and maintenance of airway management skills takes time and resources. Third, PHAAM should not be focused only on the technical performance of ETI or SAD insertion, but also on factors which occur after airway management: adequate ventilation, circulation, sedation and situations where one should refrain from PHAAM. Checklists have appeared to be effective in improving safety in health care (Thomassen *et al.* 2014) and standard operating procedures have been successfully used in pre-hospital anaesthesia (Chesters *et al.* 2014, Soti *et al.* 2015).

6.8 Other observations

6.8.1 HEMS database in research

The FinnHEMS database is one of the key factors for producing data to enable quality improvement, benchmarking as well as for research purposes in nationwide HEMS. First, all patients treated by FinnHEMS units are recorded in the database. Second, it contains a great deal of standardised data such as the location of the incident, pre-hospital time intervals and therapy performed by FinnHEMS.

The current database does, however, have its limitations and needs improvement. IDs and more detailed information are not included in the case of aborted missions, preventing any possibility to access hospital records and, for instance, FCDR. Another limitation is the physiological parameters recorded in the database. It is not mandatory to record them, so the number of lacking values may be so high that it is impossible to calculate the RTS for most of the patients, as observed in the present study. (II) A solution could be coding of respiratory frequency and systolic blood pressure (Ringdal *et al.* 2008).

Twenty-two out of 558 patients were lost to follow-up due to lacking IDs or missing hospital records. This might result from the fact that the patient ID is not always known in the pre-hospital setting. To improve this point, the correct ID should be recorded as soon as possible after the mission.

6.8.2 Death certificates in the research

Despite the overall high quality of death certificates, the municipality or time was not recorded in death certificates and had to be retrieved from either hospital records, data from road traffic investigations or forensic medical reports in 7% (144/1,959) of the cases. (I) Death certificates could be more suitable for trauma epidemiological studies if the municipality and location of the injury or estimated time from injury to death was a mandatory point in the death certificates.

As death certificates only contain information for residents in Finland, they can’t be used to study fatalities that occur in the non-resident population.

6.9 Strengths of the thesis and generalizability of the results

The present study has several strengths. First, the study was performed in a region with a high autopsy rate, making the quality of the causes of death reliable. The validity of death certificates has previously been shown to be good in Finland (Lahti & Penttila 2001).

Secondly, only a few cases were lost to follow-up and the number of quantitative variables was high. Third, the municipality of the injury was used to calculate the proportion of pre-hospital deaths. Using this, instead of the municipality of residence, makes the data more reliable when calculating the incidence of fatal injuries. Fourth, the number of cases included in the analysis was high, varying from 224 in study IV to 1,959 in study I.

The results of the study can be generalized to wide geographical areas such as the northern parts of Scandinavia and also other sparsely populated areas in Canada, Russia and Australia. (I, II)

Despite the NACA score having been used for an extended period in the Norwegian Air Ambulance services, there are no previous internationally published studies that have investigated the NACA score's correlation with mortality. This study was performed in the rescue helicopter base, where experienced anaesthesiologists performed scoring during each mission. Norwegian Air Ambulance services, trauma care and geography have similarities to those in Northern Finland. The fact that the NACA score is simple to use and can be used for demographical purposes in HEMS and that it is able to predict mortality are all observations that can be generalised for FinnHEMS, as well. (III)

The effect of training in pre-hospital airway management, or the effect of the frequency of such training in Northern Finland have not previously been studied. The number of non-valid answers was low and the study revealed many factors which need to be improved or re-evaluated: training in airway management, complications in relation to ETI and the use of sedative drugs in airway management by non-physicians with low frequency in airway management. (IV)

In conclusion, the results from this thesis may be generalized to similar systems, especially in rural areas with a low frequency of urgent EMS missions and low exposure to critical care procedures.

6.10 Limitations of the thesis

The retrospective character of the studies (I–III) can be seen as a limitation. On the other hand, it is the only appropriate method for studying causes of death. The high autopsy frequency in the present material increases the reliability of the results.

Scoring of injury severity was not performed in the study on fatal injuries (I). Therefore, it is impossible to estimate possible differences in the severity of the injuries between rural and urban areas. A national trauma registry does not exist and the scoring of all 1,959 patients in the present study would have been impossible. The aim was to obtain data on the crude incidence of fatal injuries and rural urban differences. As the material for study I consisted only of fatal injuries, it is not possible to draw definitive conclusions on whether the overall prognosis differs between rural and urban areas in Northern Finland. (I) Furthermore, as the total number of incidents remains unknown, it can only be speculated on as to whether the larger proportion of all rural injuries are fatal compared with injuries in urban areas.

In study II the main limitation is that no analysis of the trauma deaths before HEMS arrival was done, and substance abuse related to the event was not recorded. (II) This results from the current practice in HEMS, where details regarding aborted missions do not routinely contain data on IDs, injuries and so on. Also, to acquire reliable data on substance abuse linked to trauma would require a prospective setting and a large pattern of toxicological screenings. The aim of the study was to analyse trauma patients surviving in-hospital. The difference in 30-day mortality was not significant. However, there was a trend towards a higher mortality in the urban group and this observation should be further examined in future studies. A longer study period or extending the study to other bases in Finland with a higher population density might have increased the power, but at the same time also introduced other forms of bias. These could have resulted from different types of EMS, treatment protocols or the fact that therapy and training level in EMS change over time.

In study III a total of 170 patients were lost to follow-up. (III). However, it is unlikely that this caused significant bias, as the reason was incompletely filled records or transfers to other institutions. In addition, the distribution of patients lost to follow-up was quite similar across the different NACA scores.

In study IV the main limitation is that the study was conducted as a self-reporting questionnaire study, possibly leading to over- and/or underestimation of the frequency of PHAAM. (IV) A prospective study would have been the most exact method for obtaining data on PHAAM. This would have necessitated a longer time to collect the data, however, during which the airway management procedures could have been changed. A self-reporting questionnaire was evaluated as a simple and most useful method for studying PHAAM in Northern Finland. Another limitation is that the response rate was only 59%. The response rates from different hospital districts were, however, quite similar.

6.11 Clinical implications

6.11.1 Rural-urban differences

As rural areas had a higher incidence of fatal injuries, this as well as the differences in trauma types, should be kept in mind when resources are allotted for injury prevention programmes. The higher incidence of fatalities in rural areas should also have an impact on planning EMS. Long response times and wide sparsely populated rural areas necessitate the existence of volunteer first responder units and HEMS. In remote rural areas in Northern Finland, the closest HEMS unit or hospital is sometimes in a different country (Sweden, Norway). Cross-border use of resources is an alternative to compensate for extended pre-hospital times.

6.11.2 Alcohol and fatal injuries

The influence of alcohol in trauma deaths is well documented, making the prevention of injuries where alcohol is a contributing factor important (Puljula *et al.* 2013, Stewart *et al.* 2003, Vaaramo *et al.* 2014). Education and general awareness of the relationship between alcohol and injuries, especially for young people and people with an increased risk for injuries, are important factors.

6.11.3 NACA score in FinnHEMS

The NACA score is widely used in HEMS in Norway, Switzerland and Germany but is not used by FinnHEMS, making a simple comparison of services and the severity of illnesses or injuries difficult in Finland. Despite the many limitations of NACA scores, such as subjectivity, it is a simple score for defining the seriousness of the condition of patients treated in different HEMS bases. It could also be used to document the overall accuracy of dispatch criteria.

6.11.4 Pre-hospital airway management

Non-physicians in EMS performed ETI only infrequently. In addition, there are challenges in maintaining skills in airway management. Hence, the local guidelines for pre-hospital airway management should be re-evaluated. In particular, ETI coupled with the use of sedatives should only be performed by physicians or specially trained paramedics if a physician is not available and the transport time is long. The training of a limited number of paramedics is more realistic: training in an OR is easier to organise and quality is easier to control. On the other hand, the success rate to insert a SAD would be better in the situations when airway management must be performed by non-anaesthesiologists.

The context of anaesthesiologist-guided airway management in the OR in Northern Finland is not defined at the moment. During OR training, there are several points that could be learned, not only ETI or SAD insertion. Factors after successful ETI or SAD insertion should receive attention. For example, in TBI patients, the avoidance of detrimental hypo- or hyperventilation and hypotension is very important (Chesnut *et al.* 1993, Davis *et al.* 2004, Davis *et al.* 2005, Sollid *et al.* 2008). If pre-hospital ETI is performed by experienced anaesthesiologists, the incidence of desaturation has been comparable to the in-hospital environment (Nakstad *et al.* 2011).

In addition to training, standard operative airway management procedures may improve the quality and safety of PHAAM (McQueen *et al.* 2015a, Rognas *et al.* 2013c).

6.11.5 The present results and injury prevention

Pre-hospital deaths

The majority of trauma deaths in the present study occurred pre-hospital and within one hour after injury. (I) It is likely that a large proportion of these were non-survivable. The majority of the victims were found dead and could not be saved with any pre-hospital therapy. Prevention in those types of injuries remains the most important goal.

An example of the importance of prevention is the reduced incidence of childhood fatalities during the last decades and the decreased rate of fatal traffic incidents (Parkkari *et al.* 2013a). The reasons for the reduced mortality are increased traffic safety and education in awareness of high-risk situations. (Parkkari *et al.* 2015) For example, the use of seatbelts has been shown to be associated with lower mortality (Nash *et al.* 2016). It is difficult to estimate the effect of improved trauma care or access to EMS on injury-related deaths (Parkkari *et al.* 2013b, Parkkari *et al.* 2015).

In injuries that are potentially survivable, earlier detection, the right therapeutic interventions, faster transport and better trauma care including rehabilitation play an important role (Peek-Asa *et al.* 2004, Simons *et al.* 2010). In the present study, the overall mortality of the patients encountered by FinnHEMS was low. (II) On the other hand, the HEMS units treated a significant number of trauma patients (II). Even better access to HEMS in rural areas in Finland could be an intervention to compensate for the limited number of hospitals with all surgical specialities.

In panel studies the proportion of potentially or definitely preventable trauma deaths has varied from 7 to 39%, highlighting the importance of high quality in both EMS and hospital care, especially in the ER (Davis *et al.* 2014, Esposito *et al.* 1995, Kleber *et al.* 2013, Ray *et al.* 2016, Sanddal *et al.* 2011). If that holds true for EMS in Northern Finland, it is likely that HEMS have played a crucial role in the survival of the present material consisting of mixed rural-urban trauma patients. Previous panel studies should be compared with caution to trauma cases in Northern Finland as these are performed in different kinds of trauma systems and some in very urban areas. In Finland, 10-13% of in-hospital trauma deaths were evaluated as being potentially preventable, and most failures resulted from inadequate surgical decision-making or failure to recognize or treat traumatic coagulopathy (Soderlund *et al.* 2009, Vahaaho *et al.* 2014).

Suicide prevention

Suicides are an example of injuries where better EMS or trauma care has no or only a minor role - only a small proportion of the victims reached the hospital. In the present study, 29% of the fatal injuries resulted from suicides. This is in accord with other studies and health reports (Bakke & Wisborg 2011, Haagsma *et al.* 2016, Kristiansen *et al.* 2014). Suicides resulting from poisonings were excluded from the present study, which highlights that suicides by themselves are an even more important burden on the health care system and society.

Prevention of the factors leading to suicide attempts should be the priority. Prevention can consist of universal or selective prevention. The former consists of restricting access to methods of suicide, guidelines and information on how to seek help, and the latter, selective prevention in risk groups such as those with mental illness, alcohol or substance abuse and persons who have attempted suicide (Nordentoft 2011). The effect of different kinds of programmes is debated, but physicians trained in depression recognition and treatment and restricting access to suicide methods have been shown to reduce suicide rates (Mann *et al.* 2005).

LE trauma

LE falls were the most common mechanism of fatal injuries in the present study. The number of deaths resulting from falls has increased in the older population in Finland and is considered a major health concern (Korhonen *et al.* 2013). In contrast to other types of mechanisms, deaths due to LE trauma occurred most often in-hospital or after primary admission contrary to HE trauma with a high rate of pre-hospital deaths. This corresponds closely with the results reported by others (Bakke *et al.* 2014, Evans *et al.* 2010). Hence, prevention of falls is very important for persons living at home as well as in the community in general (Bakke *et al.* 2014, Bamgbade & Dearmon 2016, Cameron *et al.* 2010, Evans *et al.* 2015, Gillespie *et al.* 2012, Robertson & Gillespie 2013).

In addition to prevention of fall injuries, other factors also play a role. Early operation of patients with a hip fracture is important (Marsland *et al.* 2010). Interestingly, it was recently reported that older people and those with falls could benefit from HEMS (Andruszkow *et al.* 2016). Especially this group of trauma patients should be focused on in the dispatching of FinnHEMS, or at least, EMS units should consult a pre-hospital anaesthesiologist regarding the right level of care and pre-hospital therapy.

6.12 Further studies

The observation that an especially high proportion of pre-hospital deaths occur in rural areas should be the background, for example, for panel studies of preventable trauma deaths in the region.

A nationwide HEMS database and linkage to the FCDR and ICU consortium could make possible a prospective trauma study in all HEMS bases in Finland, with the aim of studying the role of pre-hospital times in short- and long-term outcome. Combining these registries would provide a huge opportunity to obtain improved data for trauma research in Finland. The differences between rural and urban areas would also be easier to study. For that kind of study, the main challenge is still that there is no national trauma register. One approach to overcome this shortcoming could be to include only trauma patients with NACA scores of 5 to 7. This would make the number of patients that need to be studied lower than if all the patients with minor injuries were included. The high autopsy rate and the nationwide ICU database would make the reliability of these kinds of studies high. The reliability of the FinnHEMS database should also be studied in the future.

The accuracy of HEMS dispatching is an important factor. It is not known, how often patients with severe trauma are admitted to hospital without FinnHEMS involvement and potentially do not receive the care they could benefit from. A study from Norway reported that only 51% of severely injured patients treated in hospitals received advanced care given by a pre-hospital anaesthesiologist (Wisborg *et al.* 2015). On the other hand, the proportion of cancelled missions in FinnHEMS is high.

In Northern Finland, tourism is one of the main livelihoods. Activities such as snowmobile safaris, winter sports and increased traffic cause a burden on health care, with an increased number of hospital admission and ambulatory visits. The proportion of fatal injuries and hospital admissions occurring in the non-residing population should be studied. It would also be of interest to investigate if pre-hospital response times are longer during the main tourist seasons. The results could be used to plan EMS and hospital trauma care in Northern Finland.

The impact of suicide prevention programmes and the programmes that aim to reduce alcohol consumption should be topics for future studies on the national level. Every effort should be made to document the effect of prevention interventions.

7 Conclusions

Based on the results, the following conclusions were drawn:

1. The crude incidence of fatal injuries was high (54 per 100,000 inhabitants per year) overall in Northern Finland. Nearly one-third of the fatalities were suicides. (I)
2. The influence of alcohol was documented in 42% of pre-hospital deaths. (I)
3. A larger proportion of deaths occurred on-scene in rural areas than in urban areas in Northern Finland. FinnHEMS units encountered an equal number of injured patients in rural and urban areas in Northern Finland. (I, II)
4. Urban trauma patients treated by HEMS tended to have a higher 30-day mortality than rural patients but the length of ICU LOS was similar. (II)
5. The NACA severity score is an excellent predictor of 30-day mortality for trauma patients. (III)
6. Pre-hospital advanced airway management was an uncommon procedure for most non-physicians in EMS in Northern Finland. (IV)

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