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Trauma in a Scandinavian urban setting - from socio-economic status and pre-hospital rescue times to medico-legal aspects

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Trauma in a Scandinavian urban setting

- from socio-economic status and pre-hospital
rescue times to medico-legal aspects

Ali Bagher
M.D.



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Malmö 2016

DOCTORAL DISSERTATION

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Trauma in a Scandinavian urban setting - from socio-economic status and pre-hospital rescue times to medico-legal aspects			
Abstract			
<p>Aims: Epidemiological population-based studies of patients with major trauma, including both the hospitalised and the immediately deceased undergoing medico-legal autopsy, are very rare. We studied the association between socio-economic status and major trauma, the influence of pre-hospital rescue times and trauma characteristics on mortality, and the importance of medico-legal autopsy.</p> <p>Methods: This is a retrospective cohort study of both adults and children, admitted to the Emergency Department at Malmö University Hospital between 1 January 2011 to 31 December 2013, who underwent triage classification and were classified as red trauma alarm. Individuals identified as non-natural deaths were retrieved from the Forensic Department. The New Injury Severity Score was used to define major and minor trauma.</p> <p>Results: The incidence of major trauma in Malmö was 12.7 (95% CI 10.4 - 15.0) / 100,000 person years. The incidence was higher for men than for women: 17.8 (95% CI 13.9 - 21.7) / 100,000 person years and 7.9 (95% CI 5.4 - 12.4) / 100,000 person years, respectively. Lower income ($p=0.024$) and social assistance (OR 2.3; 95% CI 1.3 - 4.1; $p=0.003$) were associated with major trauma, but level of education was not ($p=0.47$). Fifty-one per cent had a response time of ≤ 8 minutes, and 95% had a response time of ≤ 20 minutes. Patients with penetrating trauma had shorter on-scene time compared to those with blunt trauma ($p<0.01$), and 89% of the trauma population arriving to hospital by ambulance received hospital care within 60 minutes. Using multivariate regression analysis we observed that age ($p<0.001$), NISS ($p<0.001$), and penetrating injury ($p=0.009$) remained independent factors associated with mortality. Traffic (37%) and fall accidents (31%) were the leading mechanisms of injury. The overall three-month mortality rate was 10.3%. Forty-four in-hospital deaths occurred, of which 33 (75%) were sent for medico-legal autopsy and tested positive for one or multiple drugs (52% and 33%, respectively). Among all individuals with major trauma, a total of 92 (53%) patients died and 81 (47%) underwent medico-legal autopsy. Factors associated with a lower rate of medico-legal autopsies among trauma-related deaths at hospital were high age ($p<0.001$), lower NISS ($p<0.001$), longer duration between trauma and death ($p<0.001$), falls ($p=0.030$), and trauma-related infections ($p<0.001$).</p> <p>Conclusion: Major trauma was associated with lower income and social assistance, but not level of education. Total pre-hospital times of <60 minutes or response times of <8 minutes did not seem to be a crucial factor in predicting mortality in the Malmö trauma cohort. Even though penetrating traumas were associated with shorter on-scene time and shorter transport distance to hospital, mortality was increased. There was a high prevalence of drugs detected among in-hospital trauma patients undergoing forensic toxicological examination. More than half of the individuals sustaining major trauma died due to their injuries and an additional 25% of the in-hospital fatalities should have undergone medico-legal autopsy according to legislation, but did not.</p>			
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Cover picture by Dr Thomas Troëng. The picture shows a patient who stabbed herself directly in the heart with a knife in a suicide attempt as a result of deep depression.

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KLIMATKOMPENSERAT
PAPPER



To Mahya and Artin

*Wherever the art of medicine is loved,
there is also a love of humanity!*

- Hippocrates

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List of publications

This thesis is based on the following papers, which are reproduced with permission:

- I. Bagher A, Andersson L, Wingren CJ, Ottosson A, Wangefjord S, Acosta S. Socio-economic status and major trauma in a Scandinavian urban city - a population-based case-control study. *Scand J Public Health*. 2016; 44: 217-223.
- II. Bagher A, Todorova L, Andersson L, Wingren CJ, Ottosson A, Wangefjord S, Acosta S. Analysis of pre-hospital rescue times on mortality in trauma patients in a Scandinavian urban setting. *Trauma*. DOI: 10.1177/1460408616649217.
- III. Bagher A, Andersson L, Wingren CJ, Ottosson A, Wangefjord S, Acosta S. Outcome after red trauma alarm at an urban Swedish hospital: Implications for prevention. *Scand J Public Health*. 2015; 43: 506-13.
- IV. Bagher A, Wingren CJ, Ottosson A, Andersson L, Wangefjord S, Acosta S. Necessity of including medico-legal autopsy data in epidemiological surveys of individuals with major trauma. *Injury*. 2015; 46: 1515-9.

List of abbreviations

AIS	Abbreviated Injury Scale
ALS	Advanced Life Support
ATLS	Advanced Trauma Life Support
CI	Confidence Interval
CT	Computed Tomography
EMS	Emergency Medical Services
GHB	Gamma-hydroxybutyric acid
ICD-10	International Classification of Diseases - Tenth Revision
ICISS	ICD-10 Injury Severity Score
ICU	Intensive care unit
IQR	Interquartile ranges
IRR	Inter-rater reliability
ISS	Injury Severity Score
LISA	Longitudinal integration database for health insurance and labour market studies
MDMA	Methylenedioxymethamphetamine
METTS	Medical Emergency Triage and Treatment System
NISS	New Injury Severity Score
OR	Odds Ratio
RA	Registration address
RTS	Revised Trauma Score
SCANTEM	Scandinavian Networking Group for Trauma and Emergency Management
SCB	Statistics Sweden
SES	Socio-economic status
SweTrau	Swedish Trauma Registry
TPR	Total Population Register
TRISS	Trauma Score - Injury Severity Score
WHO	World Health Organization
WI	Welfare Index
SOS	International Morse Code, used as a distress code to signal danger

Introduction

Injury is an established public health issue and the largest single factor of death and severe disability in people under 40 years of age (Global Summary Estimates, WHO 2014). Yearly, 25% of all American citizens sustain an injury (Injury Prevention, American College of Surgeons 1998) and in Europe every two minutes a European dies of trauma (Eurosafe 2013). In Sweden, 4,000 individuals die annually as a result of trauma (Brattström 2010). According to the Merriam-Webster dictionary, the term “accident” is “a sudden event that is not planned or intended and that causes damage or injury” (<http://www.merriam-webster.com>). The World Health Organization (WHO) in 2002 emphasised the fact that “*Injuries have traditionally been regarded as random, unavoidable accidents. . . .but today both unintentional and intentional injuries are viewed as largely preventable events*” (Peden, WHO 2002). Accidents are therefore known often to be caused by carelessness and/or a lack of knowledge that a risk exists. Prevention of trauma is a top priority and surveys disclosing the risks of trauma are needed. Age, gender, place of residence, socio-economic status, association with alcohol and other drugs, and pre-hospital and hospital care are known factors for trauma but continued research is needed.

A thesis on trauma in Malmö, the third largest city in Sweden, has not been performed until now. Malmö Hospital receives all major traumas, and the close collaboration with the Department of Forensic Medicine in Lund is of great importance to the ability to retrieve the most complete data possible. It is rare that epidemiological surveys of patients with trauma include both those admitted to the Emergency Department and those sent for medico-legal autopsy. A multi-disciplinary collection of data is necessary, otherwise significant loss of data may occur (Hatamabadi 2011).

This thesis is based on four population-based epidemiological studies using retrospectively collected data to study trauma individuals. *Study I* describes the incidence and mortality of major trauma in all ten districts in Malmö and the association between socio-economic status and major trauma. *Study II* investigates whether pre-hospital rescue times were associated with mortality in a trauma cohort arriving at the hospital by ambulance.

In *Study III* we study mechanisms of injury and risk factors for mortality in order to find potential preventive measures. In *Study IV*, we examine the necessity and importance of including medico-legal autopsy data in an epidemiological survey of patients with major trauma.



Figure 1.

Patient with diabetes mellitus treated with an insulin pump who crashed his car due to sudden hypoglycemia. Malmö, 14/8/2015. The patient survived with only a minor fracture to his right arm. (Picture with permission of Kent Naterman, Chief of Emergency Services)



Figure 2.

Emergency services at trauma scene. The picture shows the teamwork collaboration between different medical disciplines, the fire department, pre-hospital services, and the police, which is necessary in trauma situations. (Picture with permission of Kent Naterman, Chief of Emergency Services)



Figure 3.

A truck ran a red traffic light and crashed into a van. The truck driver was in a hurry to catch the ferry. He received only some bruises and was not injured seriously, but the driver of the van was in a coma for 14 days and then died. (Picture with permission of Kent Naterman, Chief of Emergency Services)



Figure 4.

Car accident on a motorway close to Malmö. The patient survived with minor injury to the columna vertebralis. Malmö 2/12/2015. (Picture with permission of Kent Naterman, Chief of Emergency Services)

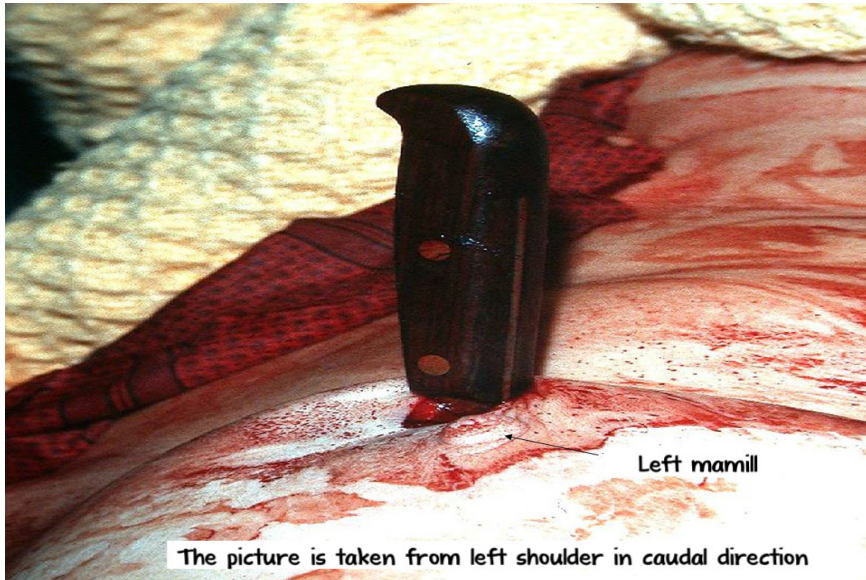


Figure 5.

The picture shows a patient who stabbed herself directly in the heart with a knife in a suicide attempt as a result of deep depression. The knife penetrated the left chamber, with bleeding to the left pleura. The hole in the heart was sutured by using pledget sutures after a left-sided thoracotomy and the patient survived. (Picture with permission of Dr Thomas Troëng)

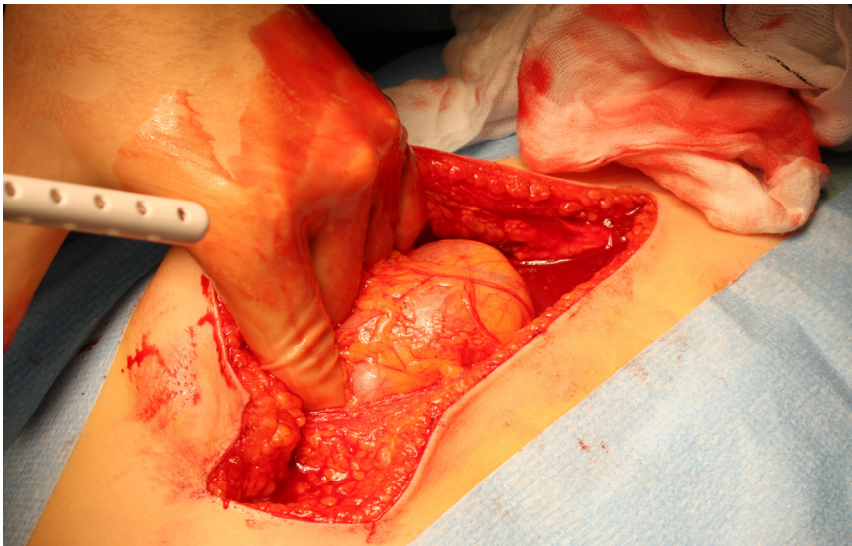


Figure 6.

Free blood in the abdomen due to rupture of the spleen in a car accident. The patient underwent a splenectomy and survived. (Picture with permission of Dr Thomas Troëng)



Figure 7.
Gunshot from a rifle to the back of the patient. (Picture with permission of Dr Thomas Troëng)



Figure 8.
Two strokes with a double-edged knife to the left glutea due to battery. The patient was found lying in the street. The injuries were deep and penetrated into the abdominal cavity, resulting in bleeding from the pelvic veins. However, the bleeding stopped spontaneously and the patient survived without surgery. Malmö, 20/9/2015. (Picture: Ali Bagher)

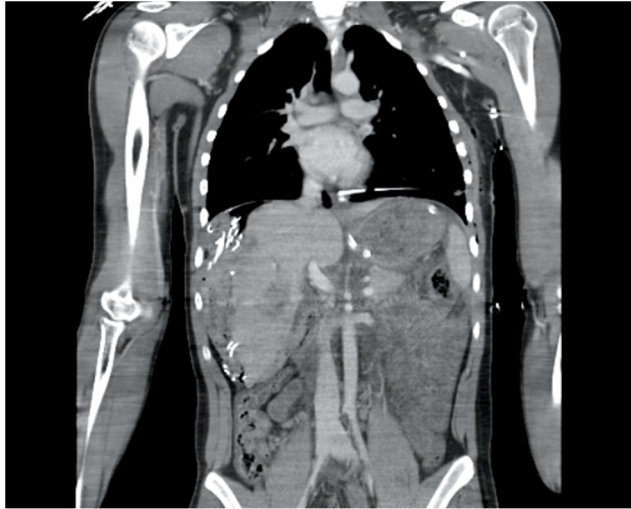


Figure 9.

Gunshots at a party. Several bullets were fired into the thorax, abdomen, and head. Two bullets were shot into the right thorax and two into the left thorax. The patient suffered from left hemothorax and bilateral pneumothorax. One gunshot to the abdomen perforated the stomach, with bleeding from the splenic vein and middle colic artery, and injured the right liver lobe, resulting in massive blood loss into the abdomen. A laparotomy with damage control was done at hospital but without any success and the patient died from gun shot wounds to the head, with severe massive intracranial injuries shown in the picture below.

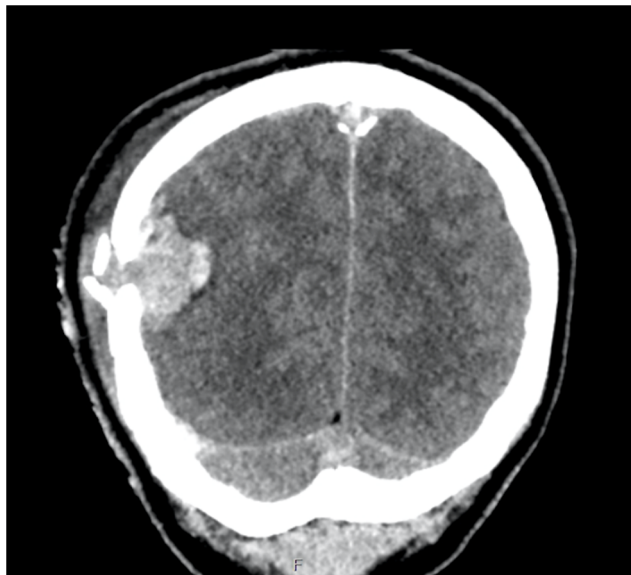


Figure 10.

One bullet hit the face and penetrated the nasal bone on its way to the right hemisphere, with parietal haemorrhage resulting in compression of the ventricles, supratentorial herniation, and high-pressure injury to the brainstem.

Background

Definition of trauma

The definition of *trauma* can vary. In this thesis it refers to a physical injury to the individual. According to a definition used by WHO (Apollo briefing, WHO 2004), trauma is defined as “*an injury that occurs when the human body is suddenly subjected to energy in amounts that exceed the threshold of physiological tolerance*”.

There is no international definition of major (severe) or minor (non-severe) trauma. Different injury severity classification systems use their own inclusion criteria of what can be classified as major/minor trauma.

Historical perspective

The first progress in trauma care in the world was made by the armed services in the middle of the twentieth century. In World War I, the quick evacuation of injured soldiers was established as standard procedure. The wounded were transported from the battlefield and initial treatments were given at the nearest battalion aid stations. This primitive medical care consisted of painkillers, the splinting of fractures, and control of external haemorrhage. Notably, in this war the time interval between injury and medical treatment was about 12 to 18 hours (Mullins 1999). Seriously injured soldiers were then evacuated to other places for emergency surgery by army surgeons.

As war casualties could suddenly result in hundreds of injured, medical priority became important, and in France, the triage (i.e. sorting of injured soldiers based on medical priorities) became standard.

In World War II, the resuscitation of wounded soldiers became quicker and better, with blood transfusions and more effective surgical treatments, all of which resulted in better survival of the most severely injured soldiers (Mullins 1999).

The development of Mobile Army Surgical Hospitals (MASHes) during the Korean and Vietnam Wars of the 1950s and 1960s was a factor that contributed to progress in trauma care, and trauma as a medical specialty began to take shape. The American Trauma Society (ATS) was founded in 1968.

Unfortunately, trauma care for civilians during the same period was not good and remained old-fashioned, and according to the ATLS, more people died of traumatic injuries in the United States than in the Vietnam War during the same time period (Mullins 1999).

The National Academy of Sciences and the National Resource Council published a report in 1966, "Accidental Death and Disability: the neglected disease of modern society" (Sciences NAO 1966), which changed the development of trauma treatment in the United States and started the centralisation of trauma care into advanced trauma centres.

ATLS

In February 1976, an orthopaedic surgeon by the name of Dr Jim Styner and his family were injured in an accident that later changed the first minutes of modern trauma management for all other injured patients in the world.

Dr Styner suddenly crashed his small plane in Nebraska. He and his children all sustained serious injuries, and his wife died instantly. The trauma management they received at the nearest medical centre was inadequate and insufficient. He stated, "When I can provide better care in the field with limited resources than what my children and I received at the primary care facility, there is something wrong with the system, and the system has to be changed."

His work towards an improvement in medical care for major trauma patients eventually resulted in the first ATLS course in 1978, and two years later the American College of Surgeons introduced this course in the United States and the rest of the world. Today, ATLS is used in nearly 60 countries and is a routine procedure in trauma care in hospitals worldwide. Recently, however, a Cochrane analysis concluded that the evidence for the effect of ATLS care on trauma outcomes is low at the present time. Actually, none of the studies in that review met the inclusion criteria and better-controlled trials were recommended (Jayaraman 2014).

Damage control

Surgeons have used the concept of damage control surgery for a long time. Dr Pringle showed this technique in patients with major hepatic injury as early as the beginning of the twentieth century (Pringle 1908).

The development of this technique later led to the article in 1993 by Rotondo and Schwab (cover picture at the back of the book), who used the term "damage control" (Rotondo 1993).

Damage control is a concept in surgery performed for trauma-related injuries and involves the initial, abbreviated treatment necessary to give the patient a better chance of survival, because the full treatment of all injuries risks the death of the patient. The

purpose of damage control is to get bleeding under control, prevent contamination, and protect from further harm.

Indications for damage control are circulatory instability, major bleeding requiring more than 10 units of blood products, or diffuse bleeding, thrombocytopenia or coagulation disorder, less than 7.3 pH, or a body temperature of less than 35 degrees.

According to this concept, the primary surgery is limited to simple, rapid actions to save lives and reduce the risk of severe complications, and restorative surgery is performed at a later stage after physiological normalisation.

Level of trauma centres

The level of trauma centre defines national standards for trauma care. Each hospital may be categorised into a certain level of trauma centre (i.e. Levels I-V). The level of trauma centre refers to the available resources in a hospital and the number of patients admitted yearly (American Trauma Society 2015).

Level I

A Level I trauma centre should provide total care for every aspect of injury - from prevention through rehabilitation.

- Is a referral centre for other nearby hospitals and has 24-hour in-house availability of general surgeons, and immediate care in specialities such as orthopaedic surgery, neurosurgery, anaesthesiology, emergency medicine, radiology, internal medicine, plastic surgery, oral and maxillofacial surgery, and pediatric and critical care
- Provides education to the hospital trauma team and has a quality-assessment programme
- Provides leadership in prevention and public education
- Conducts research to develop new findings in trauma care
- Makes special programme efforts in substance abuse screening and drug intervention
- Meets the minimum requirement for an annual volume of 600 major trauma patients per year

Level II

A Level II trauma centre is able to initiate definitive care for all injured patients.

- Has 24-hour in-house availability of general surgeons, and immediate care in specialities such as orthopaedic surgery, neurosurgery, anaesthesiology, emergency medicine, radiology, and critical care. Further treatment, such as cardiac surgery and microvascular surgery, may be referred to a Level I

centre

- Provides education to hospital staff and has a quality assessment programme
- Provides trauma prevention and public education

Level III

A Level III trauma centre is able to provide stabilisation of injured patients and emergency operations through prompt resuscitation, surgery, and intensive care.

- Offers 24-hour immediate treatment by emergency medicine doctors and the prompt availability of general surgeons and anaesthesiologists. Has made transfer agreements for patients requiring more comprehensive care at a higher level of trauma centre
- Provides education to hospital staff and has a quality assessment programme
- Is involved in trauma prevention efforts

Level IV

A Level IV trauma centre is able to provide Advanced Trauma Life Support (ATLS) prior to patients' transfer to a higher level trauma centre. Injured patients benefit from the centre's stabilisation and diagnostic capabilities.

- Offers basic emergency care according to ATLS protocols and 24-hour laboratory coverage. Physicians are available upon patient arrival. Has made transfer agreements for patients requiring more comprehensive care at a higher level trauma centre
- Provides a quality assessment programme
- Is involved in trauma prevention efforts

Level V

A Level V trauma centre is able to provide initial evaluation and stabilisation and prepares patients for transfer to higher levels of care.

- Offers basic emergency cares according to ATLS protocols and has physicians available upon patient arrival
- Has after-hours activation protocols if the centre is not open 24 hours a day
- Has made transfer agreements for patients requiring more comprehensive care at a higher level trauma centre

History of Malmö Hospital and its surgery department

Malmö Hospital moved to its current location in the Södervärn area of the city in 1896 due to Malmö's need of a bigger hospital at a time when the city was growing very fast. Dr Fritz Bauer became the manager of this new hospital and he soon split the hospital into surgical and internal medicine parts. Abdominal surgery was still rare at that time. Before Dr Bauer's time, less than one abdominal operation a year was performed in Malmö, but in 1904, 199 abdominal operations were already being performed, of which 122 were due to suspected appendicitis (Ekelund 2008). Dr Bauer was appointed head of the Red Cross ambulance and, together with other Swedish surgeons, encountered war injuries during the Balkan War in 1913 and the First World War. In this way surgery was developed at Malmö Hospital.

History of pre-hospital care in Skåne

At the beginning of the twentieth century, so-called "ill carriages" with horses were used to transport sick or injured patients (Räddningstjänsten Syd 2015) (Figure 11). However, when transporting sick or injured patients, they used "rubber skids" on the wheels for comfort. In 1917 (Figure 12), Malmö received its first motorised ambulance. In the 1950s, the county councils assumed responsibility for the ambulance services, but still with only a man and a stretcher and no other equipment in the ambulances. During the 1960s, ambulance drivers needed to undergo a 64-hour training course to get a licence to drive an ambulance. In the 1970s, a seven-week training course in emergency medical services was introduced. Until 1989, it was usually firemen who worked in the ambulances. In 2005, Skåne County was among the first counties in Sweden to require that all emergency ambulances have at least one specialist nurse (Todorova 2016).



Figure 11.
Picture of the first "ill carriage" in Malmö, 1903



Figure 12.
Picture of the first ambulance in Skåne County, 1917

Trauma in the world

According to reports from WHO in 2014 (Injuries and violence, WHO 2014), each year more than five million people die in the world because of injuries, and these tragedies often have an irrevocable impact on the lives of the families and friends of these victims. These deaths account for 9% of the world's total deaths. One-fourth are the result of homicide and suicide, and another 25% are a consequence of road-traffic injuries. But these millions of deaths are only a small number of all those patients that are injured and get medical care, but survive.

Injury is the third leading cause of lost disability-adjusted life-years worldwide (Global Summary Estimates, WHO 2014). Road-traffic injuries are the most common cause of death in the world among trauma victims aged 15-29 (Injuries and violence, WHO 2014).

Men are overrepresented overall in worldwide injury-related deaths. About 75% of the world's deaths from road-traffic injuries and 80% of those from homicide occur among men (Injuries and violence, WHO 2014).

About 90% of the injury-caused deaths occur in low/middle-income countries. Injury deaths are about three times as frequent in low/middle-income countries than in high-income countries (Injuries and violence, WHO 2014). Poor families are also usually worst hit by the financial pressure from these injuries, e.g. medical costs and lost income as a result of the injuries.

One report states that for each severely injured patient in Europe, 25 others have been in hospital care and a further 145 patients have sought outpatient care (EuroSafe 2013) (Figure 13).

Temporal distribution of trauma deaths

In a classical paper from 1983, the trimodal distribution of 862 trauma deaths over a two-year period managed at San Francisco General Hospital was reported (Trunkey 1983): the numbers of deaths were highest in the first peak, immediate deaths (within one hour of injury), corresponding to individuals who die very soon after an injury, typically as a result of severe brain damage or due to bleeding from the heart or major vessels. The numbers of deaths were lower in the the second peak, early deaths, corresponding to individuals who die within the first few hours after an injury, mainly due to major internal haemorrhage and blood loss. The third and lowest peak, late deaths, corresponded to individuals who die days or weeks after an injury, usually due to infection or multiple organ failure. In modern trauma management it seems that this trimodal distribution has changed into a bimodal distribution where only the two first peaks can be identified, whereas the incidence of late deaths has been greatly reduced (Demetriades 2005). This fact might be attributed to improvements in resuscitation and intensive care. It was shown that mechanisms of injury and the body area with severe trauma play a critical role in determining the temporal distribution of death. In particular, penetrating trauma was relatively more fatal than blunt trauma at the trauma scene, whereas blunt trauma was found to be relatively more responsible for deaths beyond one day of care. Potentially preventable deaths from bleeding after major trauma are a main objective for surgeons. The multidisciplinary Task Force for Advanced Bleeding Care in Trauma has in their updated European guidelines strongly recommended that the time elapsed between injury and operation be minimised for patients in need of urgent surgical bleeding control (Rossaint 2010). The proportion of trauma deaths, around 50% at first peak, has, however, been the same over the past decades, and calls, above all, for intensifying trauma prevention programmes in the society.

Trauma in Sweden

In Sweden, trauma is generally caused by blunt injuries (93.5%) and penetrating injuries (6.5%) (SweTrau 2013). Twenty per cent of all trauma cases undergo some kind of surgical procedure. Trauma leads to invalidism in 6.5% and death in 3.4% of cases (Troëng 2013). Most of the trauma incidents occur between 16 and 30 years of age in both men and women (Figure 14). Falls (44%) and traffic injuries (40%) were the most usual mechanisms of injuries in Sweden (SweTrau 2013) (Figure 15).

Malmö Hospital receives 700 trauma patients per year. In comparison, Karolinska Hospital in Stockholm receives 1,500 trauma patients per year, and Ullevål Hospital in Oslo, Norway receives 1,800 trauma patients per year.

The Swedish Surgical Society took the initiative in August 2008 to start a national trauma registry, named SweTrau, and implementation began in 2011. In 2013 about 26 major Swedish hospitals in the country registered their trauma patients in this database (Troëng 2013).

Even though Sweden is a relatively peaceful country with safe roads, cars, and workplaces, injured trauma patients are a daily concern. In Sweden, there are no national guidelines on trauma care organisation. Several countries in need of improvement in trauma care, such as Norway, have already developed national guidelines. In the southern part of Sweden an investigation has now started, in association with the Swedish National Board of Health and Welfare, to develop Swedish guidelines. The goal is the creation of an organisation that collaborates within and between counties and national regions, with highly qualified doctors to ensure good care of severely injured trauma patients (Ribbe 2013).

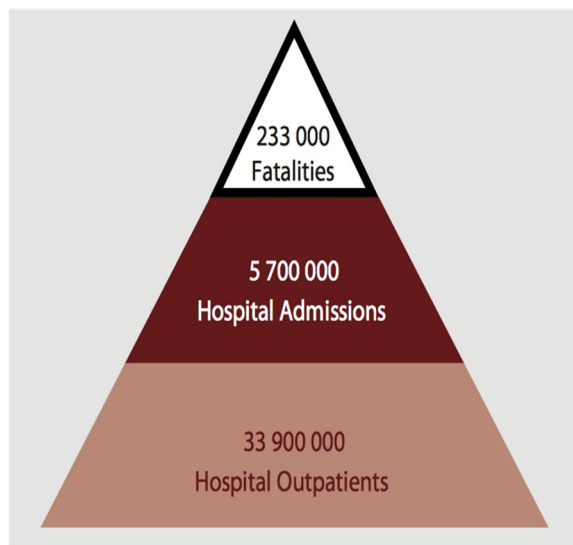


Figure 13.

Injuries in the European Union (Ref: EuroSafe, Report on injury statistics 2008-2010, Amsterdam, 2013).

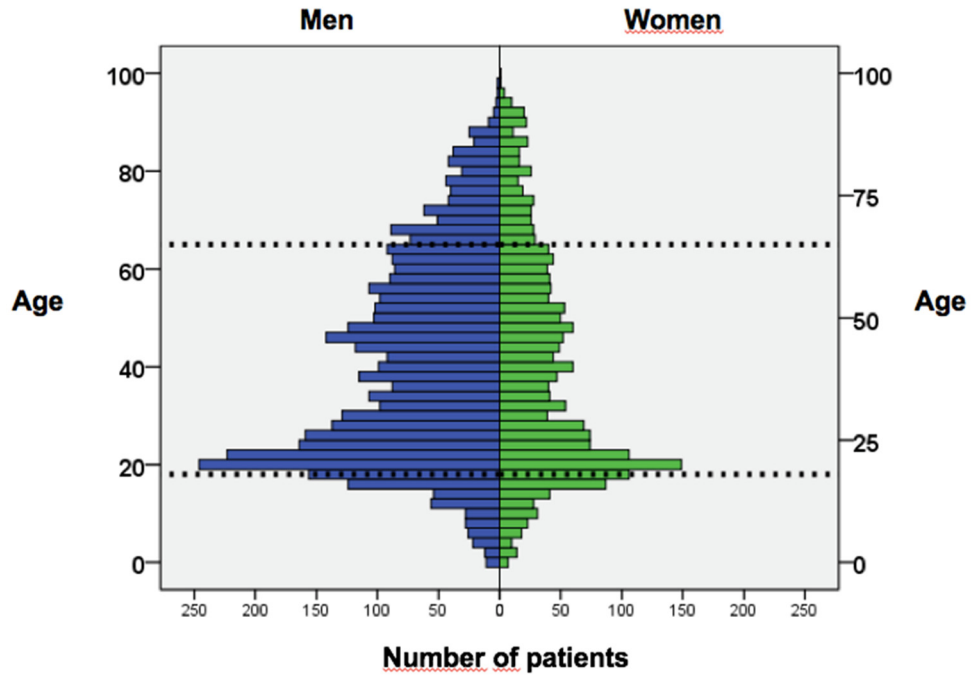


Figure 14. Age and gender distribution of Swedish trauma patients across the country registered in SweTrau in 2013 (SweTrau 2013).

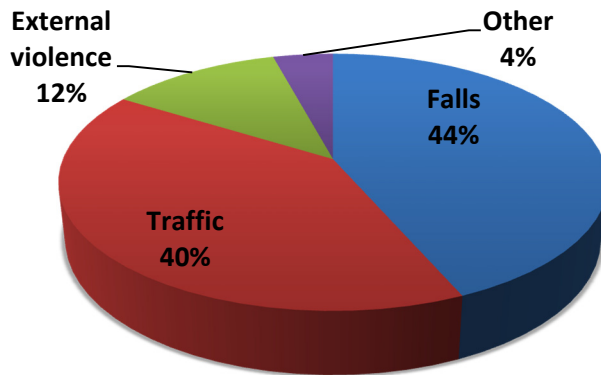


Figure 15. Mechanisms of injury in patients with NISS > 15 in Sweden (SweTrau 2013).

Trauma in Malmö

Malmö Hospital started to register red trauma alarm patients in the SweTrau database in the middle of 2013.

According to reports from SweTrau in 2014 (SweTrau 2014), 16% of the injuries in Malmö were caused by knives or other sharp objects as compared to 5% in Sweden overall, and 8% of the injuries were caused by gunshot as compared to 2% in Sweden overall. Injuries due to motor vehicle and fall accidents on the same plane in Malmö were 12% and 5% respectively, lower than the registered 26% and 11% in Sweden overall (Figures 16 and 17).

In 2014 Malmö Hospital had 129 red trauma alarms, of which five were referred from other hospitals. During the same period, Lund Hospital had 106 red trauma alarms, of which 16 were referred from other hospitals.

In the region of Skåne, the Departments of Neurosurgery and Thoracic Surgery are allocated only in Lund Hospital, whereas vascular surgery is allocated only in Malmö Hospital. These characteristics may explain the differences between these two hospitals in the volumes of referred patients.

Trauma patients in Sweden in 2014 (%)

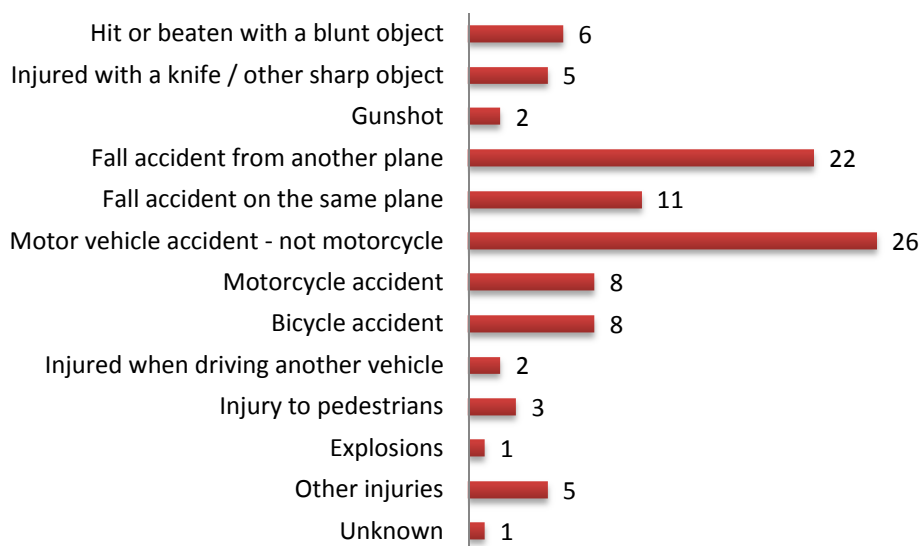


Figure 16.

Percentages of 5,444 red trauma alarm patients in 2014 in Sweden distributed according to mechanisms of injury, registered in SweTrau (SweTrau 2014).

Trauma patients in Malmö in 2014 (%)

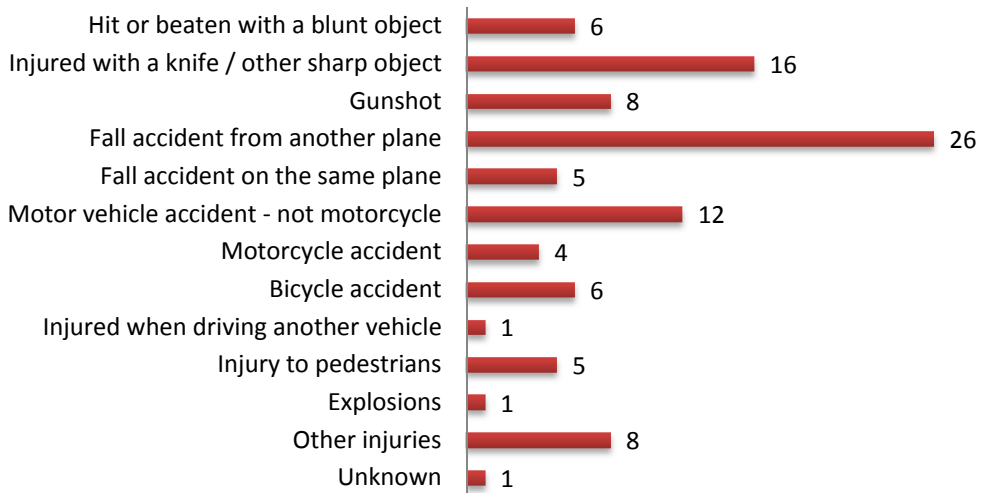


Figure 17.

Percentages of 249 red trauma alarm patients in 2014 in Malmö distributed according to mechanisms of injury, registered in SweTrau (SweTrau 2014).

Injury severity scoring classification systems

Injury severity classification is considered mandatory in trauma outcome research and quality assessment. Trauma reporting standards make data on injury severity in relation to outcome understandable and generalisable to other settings.

Several different injury classification systems have been developed and studied during the last few decades. Some of the best known and studied systems are mentioned below (Table 1).

Injury Severity Score (ISS)

This anatomical scoring system is useful above all in predicting morbidity, hospital stay, and patient mortality. Each injury is coded as an Abbreviated Injury Scale (AIS) score in all body regions (Head, Face, Chest, Abdomen, Extremities (including Pelvis), and External) (Baker 1974). The AIS classification system is a consensus-derived, anatomically based, seven-digit injury scoring system. The first six digits refer to a unique numerical identifier that designates the injured body region, the type of anatomical structure, and the specific anatomical structure; the seventh digit refers to an ordinal injury severity scale with categories ranging as follows: 1 (minor injury), 2

(moderate injury), 3 (serious injury), 4 (severe injury), 5 (critical injury), and 6 (unsurvivable injury). In this scoring system only the highest AIS score in each body region is used. The ISS score is derived by first squaring and then adding the three highest AIS scores representing the most severely injured body regions. The limitations in the ISS scoring system are that any miscalculation in AIS scoring largely changes the ISS score, and that many different patterns of injury and injuries to different body regions can result in the same ISS score.

The New Injury Severity Score (NISS)

The NISS is a classification system that also includes anatomical injury scaling. It has been recommended (Lossius 2012) and adopted by the Swedish Trauma Registry (SweTrau). The NISS seems to offer a superior performance in the prediction of mortality from blunt injuries (Tohira 2012).

Compared to physiological scoring systems, anatomical scoring systems are better prediction models for the outcomes of trauma patients (Kahloul 2014).

The NISS is superior to ISS scoring because it is calculated by summing the squares of the three highest AIS injuries, regardless of body region (Osler 1997). The NISS scale ranges from 1 to 75.

The NISS classification has been used in this thesis. $NISS > 15$ and $NISS \leq 15$ are internationally defined as major and minor trauma respectively.

ICD-10 Injury Severity Score (ICISS)

This survival prediction model is a trauma-scoring system that is defined as the product of all of a patient's survival risk ratios (i.e. the number of survivors who have a specific injury with a specific diagnosis code divided by the total number of patients who have the injury) using the codes for trauma of the International Statistical Classification of Diseases version 10 (ICD-10) (Gedeborg 2014). The ICISS accounts for all injuries that contribute to the severity of the trauma. This scoring system is useful mostly when there is a large amount of patient data. Therefore, computer assistance is often needed to calculate the ICISS trauma score.

Trauma and Injury Severity Score (TRISS)

TRISS combines the anatomical injury severity scoring (ISS) system with the physiological measures of the trauma victim - "revised trauma scoring" (systolic blood pressure, respiratory rate, the level of consciousness) - and the patient's age to predict the probability of survival (Schluter 2011). TRISS is useful for both adult and paediatric trauma. Limitations of TRISS are that the ISS used here fails to account for several injuries to the same body region, the physiological data may be unavailable or influenced by the resuscitation, and TRISS does not account for premorbid conditions.

Table 1.
Comparison of different injury severity scoring classification systems

	Anatomical	Physiological measures	Patient age	Use of ICD-10
ISS	x	-	-	-
NISS	x	-	-	-
ICISS	x	-	-	x
TRISS	x	x	x	-

An example by which to compare trauma-scoring classification systems

A 69-year-old woman involved in a car accident sustains a dashbord compression injury to the abdomen. She is circulatory unstable and complains about abdominal pain. After an initial CT scanning she is prepared for surgery. At the laparotomy, a small bowel perforation (AIS=3) is first discovered (ISS=9, NISS=9). But later on, a spleen laceration (AIS=3) and a liver laceration (AIS=3) are also noticed (the ISS score is still 9, but the NISS score is now 27). The NISS score seems advantageous and describes the severity of injuries better than the ISS, though the risk of death becomes more likely, even if these injuries are accumulating in a single body region. The ISS or NISS scores are the same regardless of gender, age, patient physical response to trauma, or the type of trauma. Calculating the probability of survival using the TRISS score in this patient with an ISS score of 9, systolic blood pressure of 90 mm Hg, respiratory rate of 25, and Glasgow coma scale of 15 would result in a 96.9% probability of survival (blunt trauma), which seems to be very high considering these three potentially lethal injuries in the abdomen of a circulatory unstable patient. The ICISS score predicts the survival risk ratios of all three of these injuries to be 78% (0.929 x 0.896 x 0.941). The Canadian benchmarks of survival risk ratios were used in this example (Bergeron 2007).

Risk factors for trauma

During the last decade research has identified the most important risk factors for trauma in an attempt to work preventively (Injury, WHO 2002; Apollo policy briefing, WHO 2004; Socioeconomic differences in injury risks, WHO 2009; Brattström 2015).

Socio-economic status

Reports from WHO have indicated a strong correlation between health and level of education (Health Impact Assessment, WHO 2015). Poor health affects one’s educational level and chances on the labour market, and therefore also one’s economic, physical, and psychosocial well-being. Reports have indicated that those with characteristics of low socio-economic status (SES), such as a lower educational level, are less healthy and suffer more often from chronic pain, depression, and anxiousness as

compared with those with a higher socio-economic status (Swedish National Institute of Public Health 2010). A recent publication on major trauma patients in Stockholm reported that a low level of education was an independent risk factor for trauma after a comparison with a municipality-matched control group (Brattström 2015).

Although the importance of SES as a risk factor for trauma injuries is well-documented (Burrows 2012, Denney 2014), the magnitude and the type of trauma vary widely by country and income level. For example, in a high-income country like Australia, the majority (88.6%) of major trauma patients have sustained their injuries from unintentional events (accidents), mostly traffic and fall accidents, and this rate is similar in the United States (Victorian State Trauma Registry 2012). In a country such as South Africa with well-known problems due to segregation and a low level of socio-economic infrastructure, interpersonal violence is the largest leading cause of death, followed by road-traffic injuries, and trauma mortality rates are seven times the global rate (Norman 2007).

Safety devices

The WHO Regional Committee for Europe resolution emphasises that the government's social and economic policies strongly influence families' susceptibility to trauma by affecting social and physical environments in the society (Laflamme 2009). It is important to identify hazards at work, home, and in commuting environments, as well as establishing community-based programmes with the intention of educating and changing people's lifestyles and behaviours (Laflamme 2009).

Health problems and mental illness

Individuals with health problems and mental illness in areas with a lower SES are at increased risk of major trauma (Brattström 2015), and their susceptibility to injury may also be due to lack of economic resources for preventive safety arrangements (Laflamme 2009).

Alcohol and drugs

Previous medico-legal autopsy series in Sweden have shown that a large proportion of fatal traffic accidents, falls, and homicides have tested positive for blood alcohol (48.4% in men and 32.9% in women) (Sjögren 2006), and that the violent suicide method of jumping from a height was related to finding the illicit drug tetrahydrocannabinol (RR 1.62; 95% CI 1.01-2.41) (Lundholm 2014). There are very few prospective studies analysing the prevalence of drugs in trauma survivors, but data available following urine toxicology screenings suggests that drug use is widespread in patients presenting with a severe or moderate injury at an urban trauma centre (26.8%) (Figl 2010) or after road accidents (43.0%) (Ricci 2008).

Pre-hospital care

During the last decade efforts have been made to improve the competence of the emergency medical services (EMS) in the Malmö region, including improved technical equipment and better delivery of advanced life support (ALS) (Todorova 2016). Previous studies have investigated whether it is better to immediately transport the injured patient to the hospital (i.e. “scoop and run/load and go”) or to treat and stabilise the patient at the trauma scene and then transport the patient (i.e. “stay and play”) (Malcolm 2009), but with conflicting results (Brendan 2006, Harmsen 2015).

There is a generally held belief that a trauma outcome after injury is improved if the total pre-hospital time is as short as possible. A pre-hospital time of less than 60 minutes after trauma - the “golden hour” - has long been an accepted goal for improving trauma care in many trauma centres. Response time, i.e. the time between a phone call to the SOS alarm services and the arrival of the ambulance to a trauma scene, has also been considered of importance. A response time of less than eight minutes has been shown to be associated with a better outcome (Brendan 2006, Harmsen 2015). Studies of the influence of pre-hospital rescue times on mortality in relation to injury severity have been conducted in other parts of the world (Carr 2006, Harmsen 2015), but this has scarcely been done in Scandinavian cities.

Hospital triage system

According to the Medical Emergency Triage and Treatment System (METTS) Adult, triage has five sorting levels, where the vital parameters and contact cause are combined to provide four priority levels (Widgren 2011). In this triage system all trauma alarms are classified as red and non-red alarms. Briefly, mechanisms of injury such as penetrating injury in the head, neck, or trunk, at least two fractures of the long bones, unstable pelvis, amputation above hand or foot, trauma with smoke or burn injury, trauma with drowning or cooling accident, unstable chest, or back injury with neurologic injury, combined with affected vital parameters such as oxygen saturation below 90%, pulse above 130 beats/minute, Reaction Level Scale above 3, breathing frequency above 30 or below 8, and systolic blood pressure below 90 mm Hg, are criteria for a red alarm.

In red trauma alarm for adults, the following staff are alerted at the university hospital in Malmö: emergency nurses, the secretary, the resident in general surgery, a specialist in general surgery, a specialist in anaesthesiology, a specialist in orthopaedics, and a specialist in intensive care. In a trauma alarm concerning children, a specialist in paediatric medicine is also alerted.

Medico-legal autopsy

In Sweden, forensic pathologists perform the medico-legal autopsy of those deceased in traumatic deaths, and by documenting the injuries they establish the cause of death and the causality between trauma and death (Kohli 2008, Töro 2005). During a medico-legal autopsy, the forensic pathologist investigates all organ systems and documents all observed injuries and disease findings, and also performs a histological examination of organs considered relevant to the cause of death. Then, based on the characteristics of the case, the pathologist determines whether bodily fluids are to be sampled for toxicological analyses and which analyses to perform. The specimens are preserved in potassium fluoride and enzyme inhibitors and are shipped refrigerated (4°C). Toxicological analyses are performed in the Department of Forensic Toxicology in Linköping, Sweden. This department handles all toxicological analyses in medico-legal autopsies performed in Sweden. The preferred bodily fluids for sampling are blood from the femoral vein, urine, and vitreous fluid. The toxicological analyses primarily cover pharmaceuticals, alcohols, and illicit drugs. The regular screening method using blood from the femoral vein covers over 220 substances, including a number of pharmaceuticals, illicit drugs, and alcohol. Usually both urine and blood from the femoral vein are screened for alcohols. Vitreous fluid is used if no urine is available and for certain specific analyses (e.g., glucose, insulin, and potassium). Some substances are not detected by the routine screening protocols and need to be specifically addressed in order to be detected (e.g., synthetic cannabinoids, lithium, glycol, and CO-hemoglobin).

Swedish law on medico-legal autopsy

Autopsy law (1995:832):

13 § A medico-legal autopsy of the deceased should be done if the examination can be assumed to be of importance for the investigation of a death that occurred in the following circumstances:

1. The possibility that the death is related to a crime cannot reasonably be disregarded, or
2. It is suspected to have been caused by a fault or negligence in health care.

14 § A forensic examination should also be done if the death is likely to have been caused by external influences and the investigation is needed to:

1. Determine the cause of death, or
2. Gain information of special importance to environmental protection, road safety, or other similar interest.

(Swedish autopsy law, <https://www.lagen.nu>)

Cemeteries Law (1990:1144):

4 § If the circumstances of a death are such that there is a need for a forensic examination under the law (1995:832), the doctor who determined that death has occurred or the one that issued the death certificate should as soon as possible notify the death to the police authority.

(Swedish cemetery law, www.lagen.nu)



Figure 18.
Frontal collision with a bus. The driver died instantly and the emergency services had to cut up the car to remove the deceased. (Picture: Emergency Services)



Figure 19.
Deceased passengers in a car accident. (Picture: Emergency Services)

Aims of the study

- To assess the association between socio-economic status and major trauma in a population-based case-control study.
- To analyse whether pre-hospital response times, on-scene times, and total pre-hospital times were associated with mortality in a trauma cohort arriving by ambulance to hospital in a Scandinavian urban setting.
- To study mechanisms of injury and risk factors for mortality in order to find potential preventive measures in patients sustaining trauma and being triaged through red trauma alarm.
- To identify factors in patients treated at hospital but not subjected to medico-legal autopsy and the extent and characteristics of trauma fatalities not registered at hospital and subjected to a medico-legal autopsy.

Disposition

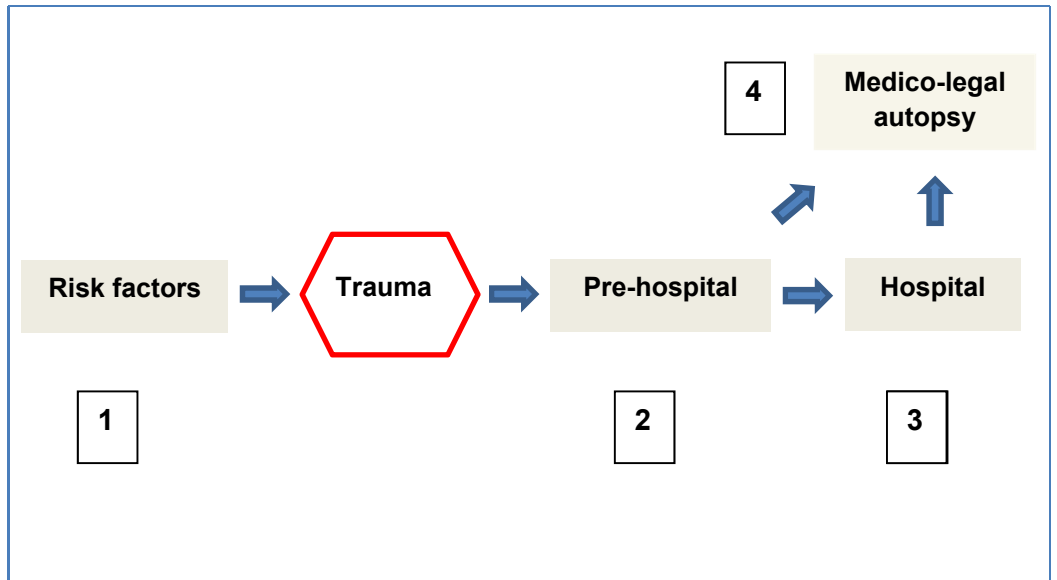


Figure 20.
Disposition of the four studies in this thesis.

Table 2.
Study design and outcome measures.

Study	I	II	III	IV
Type of study	Population-based case-control study	Retrospective cohort study	Retrospective cohort study	Retrospective cohort study
Study population	Trauma patients triaged by METTS as red trauma alarm with a registration address in Malmö between 2011 and 2013, compared to four randomly selected age-, gender-, and district-matched controls identified by Statistics Sweden	Trauma patients triaged by METTS as red trauma alarm between 2011 and 2013 and brought by ambulance to hospital	Trauma patients triaged by METTS as red trauma alarm between 2011 and 2013	Major trauma patients triaged by METTS as red trauma alarm, and individuals not registered at hospital and subjected to a medico-legal autopsy between 2011 and 2013
Study size	Cases 117 Controls 468	378	428	174
Registry	Red-trauma registry ICU trauma database Forensic Department Statistics Sweden	Red-trauma registry SOS alarm, ICU trauma database Forensic Department	Red-trauma registry ICU trauma database Forensic Department	Red-trauma registry ICU trauma database Forensic Department
Follow-up	-	3 months	3 months	3 months
Aims	Association between socio-economic status and major trauma	Analyse whether pre-hospital rescue times were associated with mortality	Mechanisms of injury and risk factors for mortality	Characteristics of trauma fatalities treated at hospital but not subjected to a medico-legal autopsy, and cases not registered at hospital but subjected to a medico-legal autopsy

Patients and methods

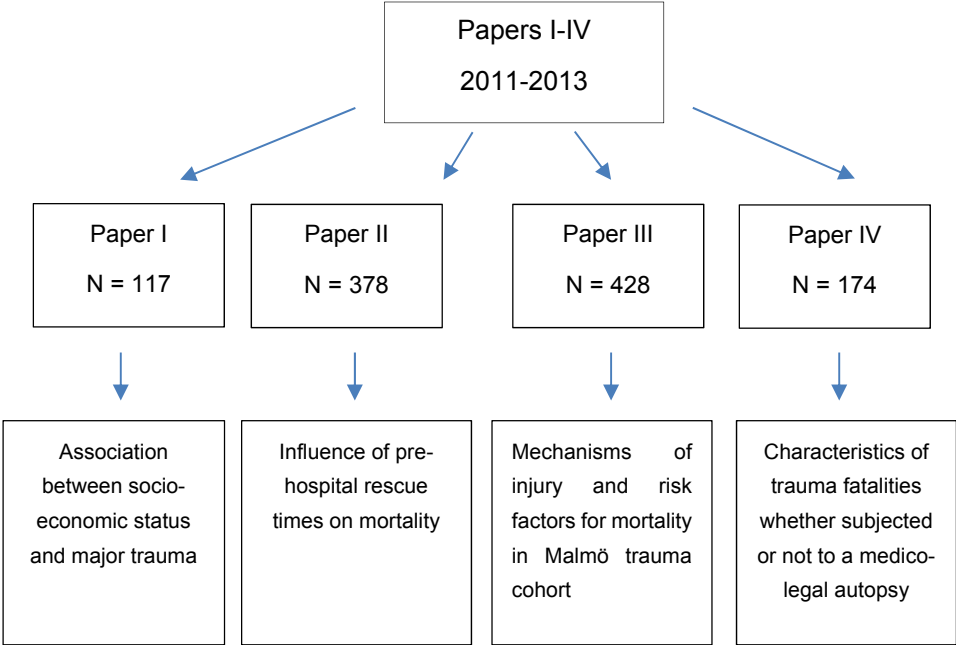


Figure 21. Overview of trauma patients, time periods, and main focus of the studies.

Ethics

The studies were approved by the Regional Ethical Review Board in Lund, Sweden (Dnr 2014/287).

Patients and settings

The Emergency Department at Malmö University Hospital has a primary catchment population of 400,000 inhabitants for major traumas. The Emergency Department has a yearly visit rate of 84,000 patients, of whom about 700 are trauma alarms. Individuals that die at the trauma scene, during transportation, or at hospital are transferred to the Department of Forensic Medicine in Lund for a medico-legal autopsy requested by the police authority. Annually, 1,000 medico-legal autopsies including toxicological analysis are performed at this forensic department. Among the 590 medico-legal autopsies requested by the Malmö police authority between 2011 and 2013, 245 revealed the cause of death to be non-natural.

The Downton fall risk index includes 11 risk factors, which are scored one point each. Scores are then added together for a total index score ranging from 0 to 11 (Rosendahl 2003). A total score of three or more indicates a high risk of falls. These risk factors include previously known falls, current medication, and sensor, cognitive, and walking disabilities.

Data collection

This thesis is based on cohort studies of both adults and children admitted to the Emergency Department at Malmö University Hospital between 1 January 2011 and 31 December 2013 who underwent triage classification according to the METTS and classified as red trauma alarm on arrival at the hospital, and on children after April 2013 classified as children trauma alarm.

Follow-up information was collected for three months following the trauma event. Patient survival was checked in the Swedish Population Registry.

Patients were identified by a combined search of all the red alarms registered in the databases in the Emergency and Anaesthesiology Departments. The databases were searched for the keyword “multi-trauma”. Beside these two registers, patients were searched for in the medico-legal autopsy register and identified using the code for “non-natural death”. In addition, nine patients that were admitted to hospital were found exclusively within the medico-legal autopsy register. These nine patients were added to the study cohort. Forty-eight individuals with major trauma from Malmö were never

triaged at hospital and were primarily transferred by the police authorities to the Department of Forensic Medicine.

The data needed was retrieved from a number of databases besides the electronic patient record system (Melior). Data concerning the level of SOS alarm priority, ambulance driving times, and patient medical condition, such as pre-hospital death before arrival at hospital, were retrieved from the scanned ambulance records from SOS Alarm and the hospital archive (Region Archive Services). The data for trauma patients who were operated on within ten hours after arrival at the hospital were retrieved from the operation planning program (Orbit). The radiological data for examinations performed within ten hours after arrival was retrieved from the Radiological Department. The data on blood transfusions was retrieved from the DoreMi database of the Department of Transfusion Medicine. Data regarding intensive care was retrieved from the PasIVA database. The nationwide forensic case-handling system Portalen was used to identify relevant fatal trauma cases subjected to a medico-legal autopsy.

Trauma patients were defined according to the Scandinavian Networking Group for Trauma and Emergency Management (Ringdahl 2008), excluding drownings, hangings, asphyxia, and burns without other traumatic injuries. Patients were excluded for the following reasons: erroneous personal identification data (n=3), burns without any other traumatic injuries (n=22), hangings (n=7), drownings (n=4), and asphyxia (n=2).

The injury severity score for each trauma patient was assessed retrospectively by NISS scoring. $NISS > 15$ and $NISS \leq 15$ are defined as major and minor trauma respectively. In 31 patients, the NISS score was calculated with the help of the medico-legal autopsy reports. Uncertainties in NISS scoring was resolved in study meetings.

Study I

All individuals with major trauma in Malmö were age-, gender-, and city district-matched with four randomly selected controls in Malmö by Statistics Sweden. Socio-economic status in terms of income, capital income, social assistance within the household, and level of education were collected for the year preceding the trauma.

Socio-economic classification

The annual income level of individuals ≥ 18 years of age was defined according to an accepted classification score from Statistics Sweden; low income EUR 0-15,273 (SEK 0-142,332), medium income EUR 15,274-37,209 (SEK 142,333-346,746), and high income $>$ EUR 37,209 Euro ($>$ SEK 346,746).

Capital income was defined as income due to, e.g., capital savings, common stock holdings, ownership of properties, or shares of a business.

Social assistance within a household is statutory economic help to those families with limited economic resources.

In our study the level of education in individuals ≥ 25 years of age was defined as low (elementary school or less), medium (high school), or high (any higher education after high school), corresponding to ≤ 9 years, 10-12 years and >12 years of schooling respectively. Twenty-five years of age was considered a reasonable age for reaching a final educational level.

Study II

Definition of pre-hospital time intervals

Response time was defined as the time from the initial call for medical assistance to the time when the ambulance got to the trauma scene. On-scene time was the time spent at the scene for treatment and loading of the patient, and transportation time was the time from departure from the trauma scene to arrival at the hospital for definitive care. Total pre-hospital time was defined as the total time spent between the emergency call and arrival at the hospital (Figure 22). All pre-hospital time intervals were measured as continuous in minutes and also categorised: response time (≤ 8 minutes) (Eisenberg 1979), on-scene time (<10 minutes, 10-19 minutes, and ≥ 20 minutes) (Harmsen 2015), and total pre-hospital time (≤ 60 minutes) (Sampalis 1993). The transport distance between the trauma scene and Malmö Hospital was expressed in kilometres (km) using the shortest roadway distance shown by Google Maps (<https://www.google.se/maps>).

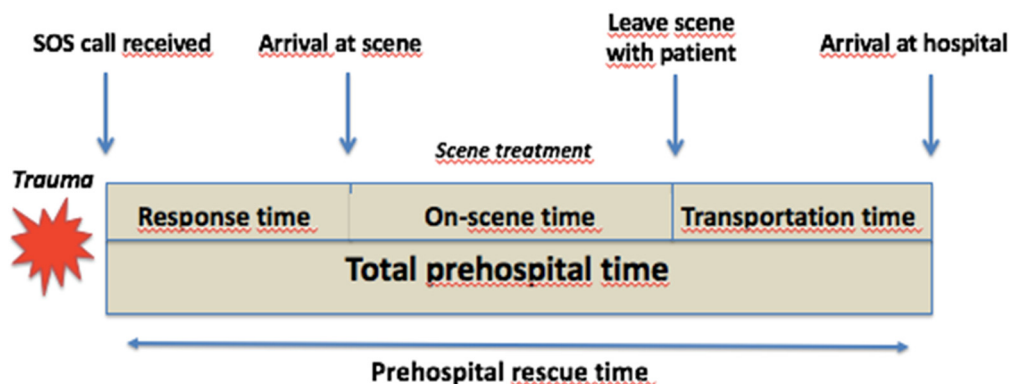


Figure 22. Pre-hospital rescue time classified according to different time intervals.

Study III

All radiological examinations were classified into three different categories (trauma computer tomography (CT), which includes CT of the head, neck, thorax, and abdomen; non-trauma CT or MR of one body region or extra CT/MR of other body regions; any X-ray).

Study IV

During a medico-legal autopsy the forensic pathologist documents all external and internal injuries and signs of disease. A histological examination of selected organs is performed in the majority of cases. Based on the characteristics of the case, the forensic pathologist determines whether body fluids are to be sampled for toxicological analyses and select analyses. Based on the findings during the autopsy and the results of the additional investigations, the forensic pathologist determines the cause and manner of death and the causal association between the injuries and disease states.

Statistical methods

Data management and statistical analysis were performed using SPSS for Windows, version 20.0 (SPSS Inc., Chicago, IL). Differences in proportions were analysed using Kendall's tau-b test, the chi-squared test, or Fisher's exact test, and expressed in p-values and, when appropriate, in odds ratios (OR) with 95% confidence intervals (CI). Continuous variables were expressed as medians and interquartile ranges (IQR), and group differences were evaluated with the Mann-Whitney U test. P-values <0.05 were considered significant. Independent covariates associated with mortality were analysed in a multi-variable regression model and expressed as OR with 95% CI. Twenty patients with NISS>15 and twenty patients with NISS≤15 were randomly generated from the SPSS programme to be rated again, after a time interval of three months from the first rating, by the second NISS rater. The two raters were residents in emergency medicine and surgery respectively. The inter-rater reliability (i.e. the consistency in the rating of subjects, although each subject is not provided exactly the same rating by all assessors) between the first and second NISS rater was evaluated with an intra-class correlation (ICC) with 95% CI, and a value of >0.7 was regarded as satisfactory (Bland 1997). The inter-rater agreement (i.e. the extent to which assessors make exactly the same judgment about a subject) was evaluated with proportional agreement and expressed as a percentage of agreement. Inter-rater agreement was graded as follows: lack of agreement (0.00 - 0.30), weak agreement (0.31 - 0.50), moderate agreement (0.51 - 0.70), strong agreement (0.71 - 0.90), and very strong agreement (0.91 - 1.00) (LeBreton 2008).

In *Study I* the incidence rate of the population at risk during the study time of three continuous years was expressed with 95% CI per 100,000 person years, and the cause-specific mortality ratios in relation to gender in all ten districts were expressed with 95% CI per 1,000 deaths. Spearman's correlation coefficient (r) was used to evaluate the correlation between mechanism of injury and income, social assistance, or level of education. Levels of income were converted from Swedish Crowns (SEK) to Euros (EUR) by using the mean average exchange rate in 2012 (<https://www.oanda.com>; SEK 100 = EUR 10.73).

In *Study IV* cause-specific mortality ratios were expressed as the number of deaths from major trauma per thousand forensic autopsies. Incidence rates were based on the overall number of hospitalised and medico-legal autopsy-verified major trauma cases respectively, and were expressed as a number of cases per 100,000 person years. Confidence intervals were calculated assuming a Poisson distribution of events, using the normal approximation method for numbers >15 .

Results

Patients

Malmö Hospital receives about 600-700 trauma alarms yearly (Figure 23).

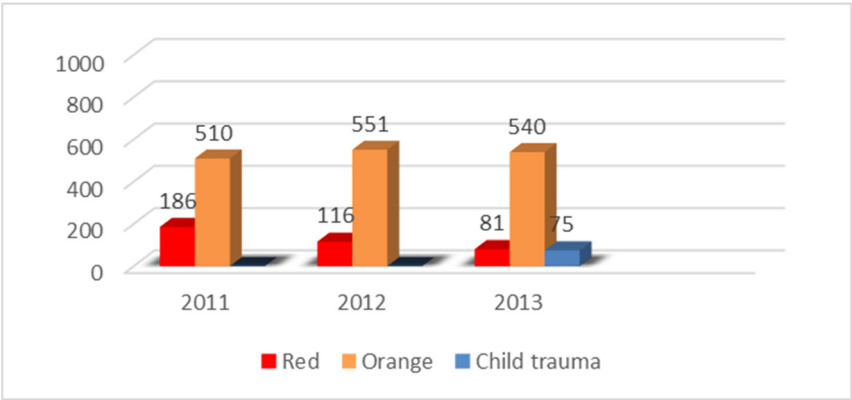


Figure 23.
Trauma alarm - Malmö Hospital between 2011 and 2013.

Validity of the study register

Forty-four patients with vascular trauma were identified in the local vascular registry. Fourteen of these patients arrived alive at the Emergency Department and met the METTS criteria for red trauma alarm and serious injury (AIS ≥ 3) within the hospital. Of these, 11 were included in the present study register. In our study register we could identify a total of 158 patients with serious injury. The validity of our study register has been calculated as 98.1% (158/161). All three patients that not were identified in our study register had an aortic transection and were transferred from other hospitals in the region directly to the operation theatre within 24 hours of the trauma event.

Inter-rater reliability

The inter-rater reliability expressed as an intra-class correlation coefficient between the first and second rater was 0.83 (95% CI 0.58 - 0.94) in the 20 trauma patients categorised as NISS >15 by the first rater. The intra-class correlation coefficient between the first and second rater was 0.96 (95% CI 0.89 - 0.98) in the 20 trauma patients categorised as NISS ≤15 by the first rater. The second rater upgraded one patient from an NISS score of 12 to 17, and downgraded one patient from an NISS score of 16 to 13. Agreement between raters according to group allocation (NISS >15 or NISS ≤15) was 95% (19/20) and 95% (19/20) respectively. Among trauma victims undergoing medico-legal autopsy, the inter-rater reliability was evaluated in two different subgroups of 20 individuals: the ICC was 0.92 (95% CI 0.80 - 0.97) and 0.96 (95% CI 0.90 - 0.98) respectively.

Study I

Patient characteristics of individuals with major trauma

One hundred and seventeen individuals with major trauma, 80 men and 37 women, were identified as residents of Malmö according to the city population register. The median age was 48.0 years (IQR 28.5-65.0), and seven (6%) cases were children. Among all cases with major trauma, 63 (54%) were caused by accidents, 30 (26%) were self-inflicted, and 20 (17%) were caused by assault/homicide. In four cases (3%) the cause of the trauma was unclear. Forty-four (34%) out of the 117 individuals with major trauma were involved in falls and 33 (28%) had road-traffic injuries. Thirty (26%) were subjected to penetrating trauma (e.g., gunshot or sharp objects).

Comparison of trauma scene and registration address in individuals with major trauma in Malmö

Figures 24 and 25 show differences in the respective distribution of the trauma individuals' registration addresses and trauma scene addresses in the ten different city districts in Malmö. Eight per cent of the major trauma individuals lived in the city district (Centrum), whereas 20% of the major traumas occurred in this city district. Comparing these two maps also demonstrates that in the two districts with the highest proportion of the trauma patients' registration addresses (RA), i.e. Fosie and Hyllie, 15% and 21% respectively, the incidence of major trauma in those districts was higher in one (Fosie - 19%) and lower in the other (Hyllie - 11%). Surprisingly, one-fifth of all trauma patients in the city of Malmö lived in Västra Innerstaden (RA 10%) and Limhamn-Bunkeflo (RA 9%), the two districts with the highest Welfare Index.



Figure 24.
Trauma individuals' registration addresses in Malmö according to district.

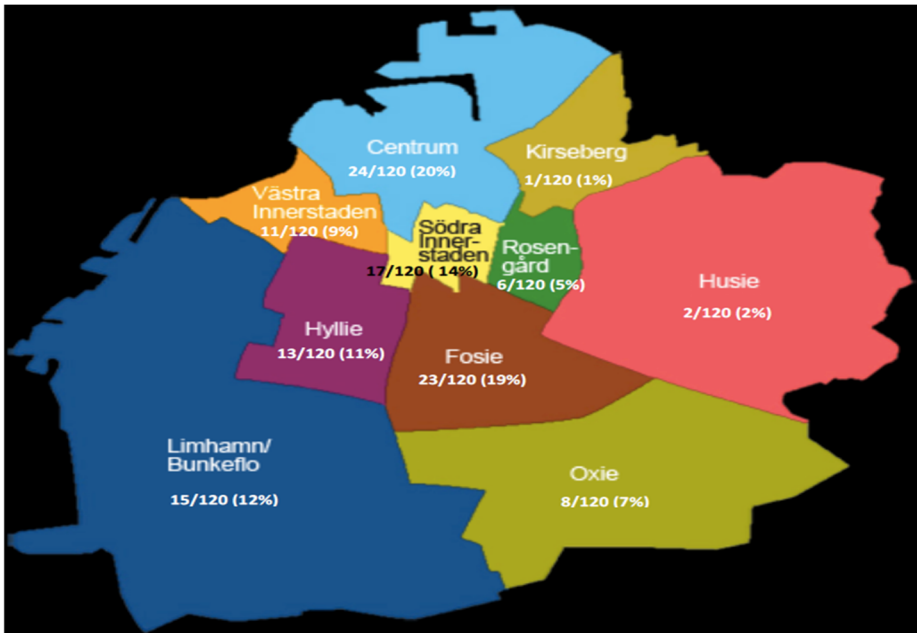


Figure 25.
Trauma scene addresses in Malmö according to district.

Distributing the trauma scene addresses by city district for all major trauma patients with a registration address in Malmö showed that the highest proportion of major trauma occurred among those from the district Hyllie (20.5%), followed by Fosie (15.4%), whereas those from the districts of Husie and Kirseberg had the lowest proportion of major trauma at 3.4% each.

Incidence of major trauma

The incidence of major trauma in Malmö was 12.7 (95% CI 10.4 - 15.0) / 100,000 person years. The incidence was higher for men than for women, at 17.8 (95% CI 13.9 - 21.7) / 100,000 person years and 7.9 (95% CI 5.4 - 12.4) / 100,000 person years respectively.

Mortality of major trauma

The cause-specific mortality ratios in relation to gender in the ten districts in Malmö were studied. Sixty-nine individuals died due to major trauma (45 men and 24 women), which corresponded to an overall trauma-related mortality of 8.4 (95% CI 6.4 - 10.4) / 1,000 deaths in Malmö citizens. The mortality rate was higher for men than for women, at 12.0 (95% CI 8.5 - 15.5) / 1,000 deaths and 5.4 (95% CI 3.2 - 7.6) / 1,000 deaths respectively.

Correlation between socio-economic status and major trauma

Social assistance within a household was significantly inversely correlated with fall accidents ($r=-0.193$; $p=0.037$). Fall accidents were correlated with age ($r=0.36$; $p<0.001$) and social assistance was correlated with lower age ($r=0.185$; $p=0.046$). There was a significant correlation between level of education and income ($r=0.192$; $p<0.001$).

Socio-economic status

Income for the major trauma victims was lower than that of the control group ($p=0.024$) (Table 3). Sixty-four (58.2%) out of 117 cases with major trauma had no income, compared to 47.0% for the controls (OR 1.6; 95% CI 1.0 - 2.4; $p=0.037$). Only 5.5% of cases with major trauma had high income. The proportion of cases that received social assistance within a household was 18.8% in those with major trauma

and 9.0% in the control group (OR 2.3; 95% CI 1.3 - 4.1; p=0.003). There was no difference in capital income or level of education between the two groups.

Table 3.

Socio-economic status in patients with major trauma in relation to age-, gender-, and city district-matched controls in Malmö.

	Cases (n=117) (%)	Controls (n=468) (%)	P-value	OR (95% CI)
Income²				
Low	81/110 (73.6)	285/440 (64.8)		
Medium	23/110 (20.9)	93/440 (21.1)		
High	6/110 (5.5)	62/440 (14.1)	0.024	
No income²	64/110 (58.2)	207/440 (47.0)	0.037	1.6 (1.0 - 2.4)
Capital income²				
Deficit	45/110 (41)	188/440 (42.7)		
None	33/110 (30)	130/440 (29.5)		
Profit	32/110 (29)	122/440 (27.7)	0.72	
Social assistance within household	22/117 (18.8)	42/468 (9.0)	0.003	2.3 (1.3 - 4.1)
Education level¹				
Low	28/94 (29.8)	87/363 (24.0)		
Medium	38/94 (40.4)	165/363 (45.5)		
High	28/94 (29.8)	111/363 (30.5)	0.47	
Low vs medium/high	28/94 (29.8)	87/363 (24.0)	0.25	1.3 (0.8 - 2.2)

¹ ≥ 25 years. ² ≥ 18 years

Study II

Comparison of pre-hospital rescue times with trauma characteristics

Three-hundred and seventy-eight patients were studied. The overall median response time was eight minutes (IQR 6-12), the overall median on-scene time was 17 minutes (IQR 11-23), and the overall median total pre-hospital time was 35 minutes (IQR 27-46) for the 378 eligible trauma patients. The on-scene time (p<0.05) and total pre-hospital time (p<0.05) were longer for patients ≥ 65 years of age, as compared with patients <65 years of age.

There was a shorter on-scene time (p<0.01) and total pre-hospital time (p<0.01) in assault/homicide patients compared to both accident and self-inflicted trauma patients.

The patients who had self-inflicted injuries had a prolonged ($p<0.05$) on-scene time of 19 minutes (IQR 15-25) compared with those with non-self-inflicted injuries. The patients with penetrating trauma had a shorter on-scene time ($p<0.01$) and total pre-hospital time ($p<0.01$) compared to those with blunt trauma.

The median NISS score in patients with penetrating injuries was 6 (IQR 3-17), compared to 8 (IQR 1-18) for those with blunt injuries ($p=0.89$).

Patients with penetrating trauma were in shock on admission to hospital in 17% (11/66) of cases, compared to 10.8% (31/286) of blunt trauma injuries ($p=0.27$).

The on-scene time was shorter for injuries from gunshot ($p<0.05$) and from knives or penetrating objects ($p<0.05$), compared to those without these injury mechanisms.

Individuals with fall injuries, as compared to non-fall injuries, had a significantly longer on-scene ($p<0.01$) and total pre-hospital time ($p<0.05$).

The median transport distance from trauma scene to hospital was significantly shorter in the case of penetrating injuries compared to blunt injuries: 3.4 km (IQR 2.4-4.7) and 4.4 km (IQR 2.9-10) respectively ($p=0.004$).

Comparison of pre-hospital rescue times with severity of injury

Patients assessed as major trauma (NISS >15) in hospital were found to have the same pre-hospital rescue times as those with minor trauma (NISS ≤ 15). Patients with serious organ injuries (AIS ≥ 3 ; $n=146$) in either the head-neck, thorax, abdomen, and/or pelvis-extremities regions were found to have the same pre-hospital rescue times as those with AIS <3 in all body regions.

Pre-hospital time intervals and injury severity in relation to mortality

Eighty-nine per cent of the patient population received hospital care within 60 minutes. There was no difference in mortality when comparing patients with and without total pre-hospital times within 60 minutes: 11% (36/320) and 11% (4/38) respectively ($p=0.89$). Fifty-one per cent had a response time of ≤ 8 min, and 95% had a response time of ≤ 20 minutes. The overall mortality rate within three months was 11% in this trauma population. Forty-four per cent of patients aged 65 and older died due to the trauma, compared to 7% of those younger than 65 ($p<0.001$). NISS >15 ($p<0.001$) and NISS ≥ 25 ($p<0.001$) were associated with increased mortality. The mortality was higher ($p<0.001$) in trauma patients with shock, versus those without shock, on admission to hospital.

The median ages among survivors and non-survivors were 29 (IQR 18-48) and 63 (IQR 44-83) respectively ($p < 0.001$). The median NISS scores among survivors and non-survivors were 6 (IQR 1-14) and 38 (IQR 27-59) respectively ($p < 0.001$). The median response times among survivors and non-survivors were 9 minutes (IQR 6-12) and 8 minutes (IQR 5-11) respectively ($p = 0.33$). The median on-scene times among survivors and non-survivors were 17 minutes (IQR 12-23) and 15 minutes (IQR 10-22) respectively ($p = 0.32$). The median total pre-hospital times among survivors and non-survivors were 35 minutes (IQR 27-45) and 32 minutes (IQR 25-52) respectively ($p = 0.56$).

On entering age, NISS, penetrating versus blunt injury, response time, and on-scene time in a multivariate regression analysis, age ($p < 0.001$), NISS ($p < 0.001$), and penetrating injury ($p = 0.009$) remained independent factors associated with mortality (Table 4).

On entering age, NISS, penetrating versus blunt injury, and total pre-hospital time in a multivariate regression analysis, age ($p < 0.001$), NISS ($p < 0.001$), and penetrating injury ($p = 0.005$) remained independent factors associated with mortality.

Table 4.
Analysis of variables associated with mortality

Variable	Mortality within three months	
	Univariate analysis (p-value)	Multivariate analysis (p-value)
Age (years)	< 0.001	< 0.001
Pre-hospital times (minutes)		
Response time	0.33	0.50
On-scene time	0.32	0.093
Severity of injury		
NISS	< 0.001	< 0.001
Mechanisms of injury		
Penetrating versus blunt	0.21	0.009

Comparison of patient characteristics between trauma patients arriving at the hospital by ambulance versus not by ambulance

Table 5 shows that median age was significantly higher in those arriving at the hospital by ambulance compared to those not arriving by ambulance: 30 (IQR 18-50) versus 24 (IQR 9-36) respectively ($p < 0.001$). The NISS score was significantly higher in those arriving at the hospital by ambulance compared to those arriving not by ambulance: 8 (IQR 2-17) and 3 (IQR 1-10) respectively ($p < 0.001$). There was a trend showing that

mortality was higher in trauma patients arriving by ambulance compared to those arriving not by ambulance ($p=0.050$).

Table 5.

Comparison of patient characteristics between trauma patients arriving at the hospital by ambulance versus not by ambulance

	Arrival by ambulance (%)	Arrival not by ambulance (%)	P-value
Patients	397 (93)	31 (7)	
Median age (IQR)	30 (18-50)	24 (9-36)	< 0.001
NISS score (median; IQR)	8 (2-17)	3 (1-10)	< 0.001
Children (<18 years)	86 (22)	11 (36)	0.077
Elderly (≥ 65 years)	46 (12)	2 (7)	0.56
Men/Women	273 (69) / 124 (31)	24 (77) / 7 (23)	0.31
Mortality	44 (11)	0 (0)	0.050

Study III

Patient characteristics

Patients with major trauma were older, less often subject to assault and battery, and more often brought to hospital by ambulance, compared to patients with minor trauma. Twenty-eight (58%) out of the 48 elderly were involved in fall accidents ($p<0.001$). Road-traffic accidents occurred more often in younger adults between 19 and 64 years of age compared to the elderly ($p=0.035$).

The gender and age-specific distribution of trauma events in Malmö is shown in Figure 26. The analysis of mechanisms of injury of men and women (Figures 27 and 28) shows that men are more likely to be involved in assaults/batteries (16%) than women (4%) ($p<0.001$), and women are more likely to be involved in fall accidents (35%) than men (22%) ($p=0.002$).

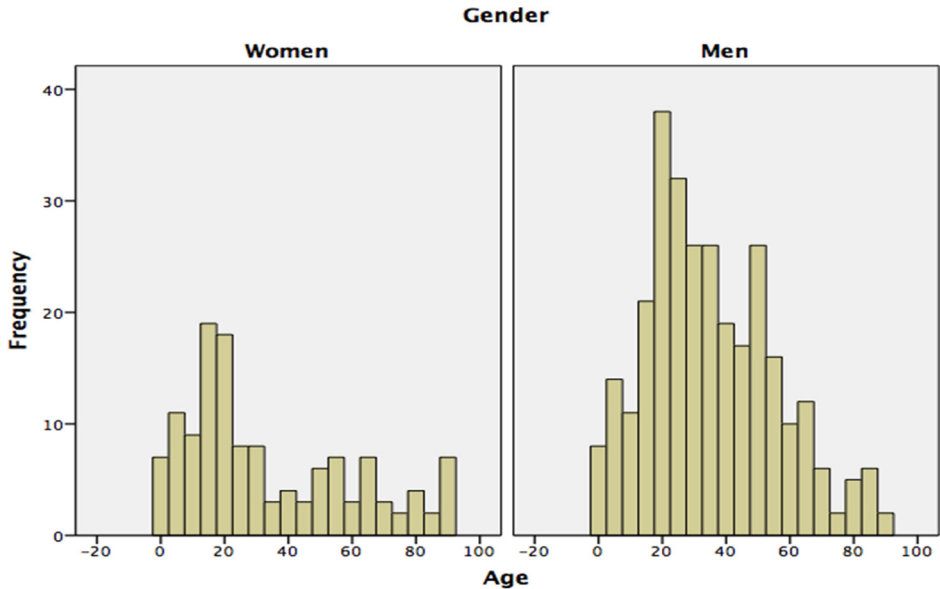


Figure 26.
Age distribution among all red trauma alarms between 2011 and 2013.

In-hospital management

Patients with major trauma underwent trauma CT more often ($p < 0.001$), non-trauma CT or MR less often ($p = 0.030$), and an emergency operation more often ($p < 0.001$), and they were more often treated in the ICU ($p < 0.001$) and they received more often blood transfusion products ($p < 0.001$) than patients with minor trauma.

Trauma radiology in children

In all children with major trauma included in Study III, 80% underwent CT, in all cases trauma CT. In comparison, only half (55%) of the children underwent CT after minor trauma, and in most cases (67%) this was non-trauma CT.

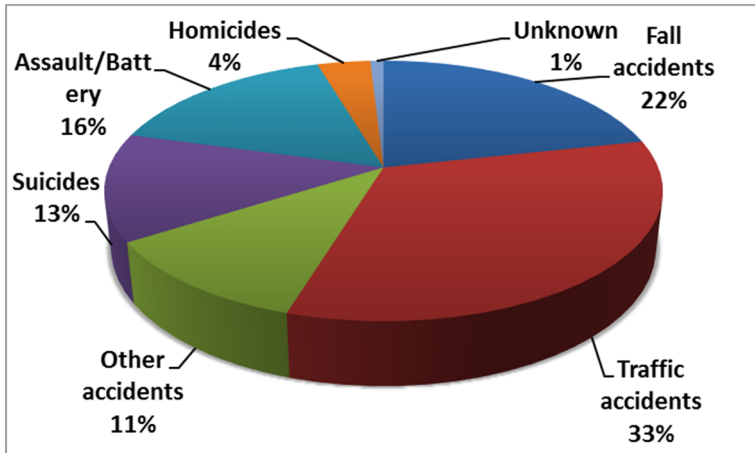


Figure 27.
Mechanisms of injury in men.

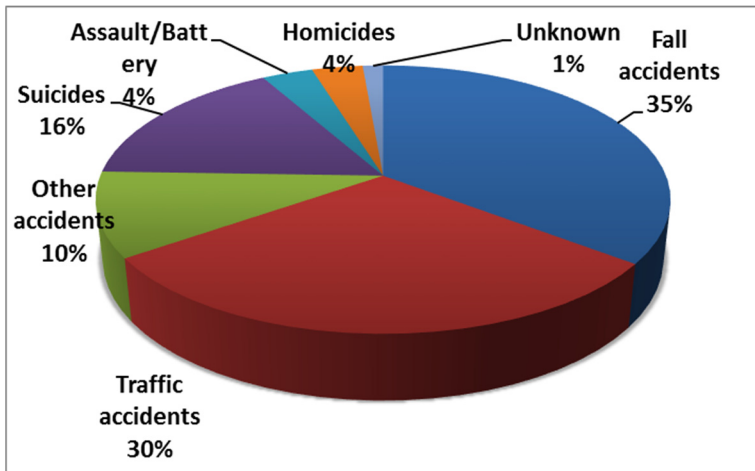


Figure 28.
Mechanisms of injury in women.

Outcomes

Patients with major trauma had a longer in-hospital stay ($p < 0.001$), were less often discharged to their home ($p < 0.001$), and were more often discharged to a rehabilitation centre ($p = 0.002$) or a non-surgical ward ($p < 0.001$) compared to minor trauma patients. Mortality was higher among major trauma patients ($p < 0.001$). Forty-four (10.3%) of all 428 patients died within three months, but only 33 of these underwent medico-legal

autopsy. Intracranial injuries were the most common cause of death, followed by hypovolemic shock, at 52% and 19% respectively (Figure 29).

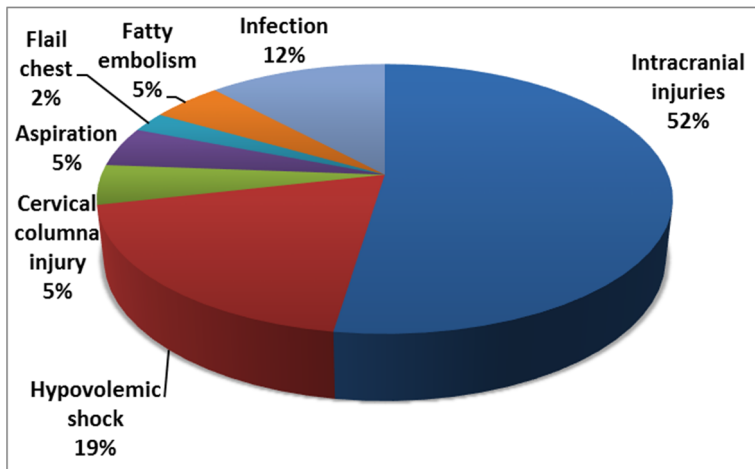


Figure 29. Death causes in trauma patients treated at Malmö Hospital between 2011 and 2013 (n=42).

Medico-legal autopsy

Thirty-three patients underwent medico-legal autopsy and toxicological examination. The median age was 55 (IQR 30 - 66), and 19 (58%) were men and 14 (42%) were women. The median NISS score was 50 (IQR 34 - 75). The patients died due to accidents (65%; 21/32), homicide (22%; 7/32), and suicide (13%; 4/32). The mode of death was unclear in one case. Fourteen out of 21 (66%) accidents were traffic accidents. The type of trauma was penetrating in nine cases (27%) and blunt in 24 cases (73%). All seven murdered patients had penetrating trauma, which in four cases was from gunshot.

Forensic toxicological examination

The median time from trauma to death was <1 day (range 0 - 32) in those 33 patients undergoing medico-legal autopsy. Twenty-four (73%) died within the first day. Seventeen (52%) of the 33 patients tested positive for drugs. The toxicological examinations were positive for ethanol in five (15%), anti-depressives in five (15%), sedatives in four (12%), analgesics in five (15%), and illicit drugs in four (12%) (Figure 30). The detected illicit drugs were amphetamines and tetrahydrocannabinol in two cases each. Opioids, tramadol, dextropropoxyphen, and paracetamol were found in three,

two, one, and one cases respectively. Two patients who died after self-inflicted trauma tested positive for anti-depressives. Eleven (33%) of the 33 patients tested positive for more than one drug.

<i>Patients (n=33)</i>	
Toxicology	(%)
Alcohol	15
Anti-depressives	15
Sedatives	12
Illegal drugs	12

Figure 30.
Toxicology findings in 33 patients who were referred for medico-legal autopsy.

Factors associated with mortality at three months

A higher NISS score ($p < 0.001$) and greater age ($p < 0.001$) were associated with mortality. Severe head and neck, severe thorax, severe abdomen, and severe extremity injuries, shock at admission, ICU stay, and administration of massive red blood cell transfusions were associated with mortality at three months in a uni-variable analysis. After entering the NISS, age ≥ 65 years, and shock at admission in a multi-variable regression model, the NISS (OR 1.2; 95% CI 1.1 - 1.2), age ≥ 65 years (OR 33.3; 95% CI 9.0 - 122.9), and shock at admission (OR 5.7; 95% CI 1.5 - 22.1) remained independent variables associated with mortality.

Study IV

Epidemiology of major trauma

The overall incidence of major trauma was estimated as 14.5 (95% CI 12.1 - 16.9) / 100,000 person years. The incidence of hospitalised major trauma patients was 10.5 (95% CI 8.7 - 12.3) / 100,000 person years. The incidence of medico-legal autopsy-verified individuals sustaining major trauma was 6.8 (95% CI 5.3 - 8.3) / 100,000 person years. The mortality rate among hospitalised patients was 34.9% (44/126). Deaths occurred in-hospital in 47.8% (44/92) and ex-hospital in 52.2% (48/92). The trauma-specific mortality ratio among those undergoing medico-legal autopsy was 137 (81/590) per thousand forensic autopsies.

Outcome of major trauma in Malmö

126 patients were first admitted to hospital, and 48 cases were sent directly from the accident site to the Department of Forensic Medicine (Figure 31). Among the 126 patients admitted to hospital, 33 fatalities were sent to the Department of Forensic Medicine. Among all 174 individuals in total, 92 (53%) died and 81 (47%) underwent medico-legal autopsy.

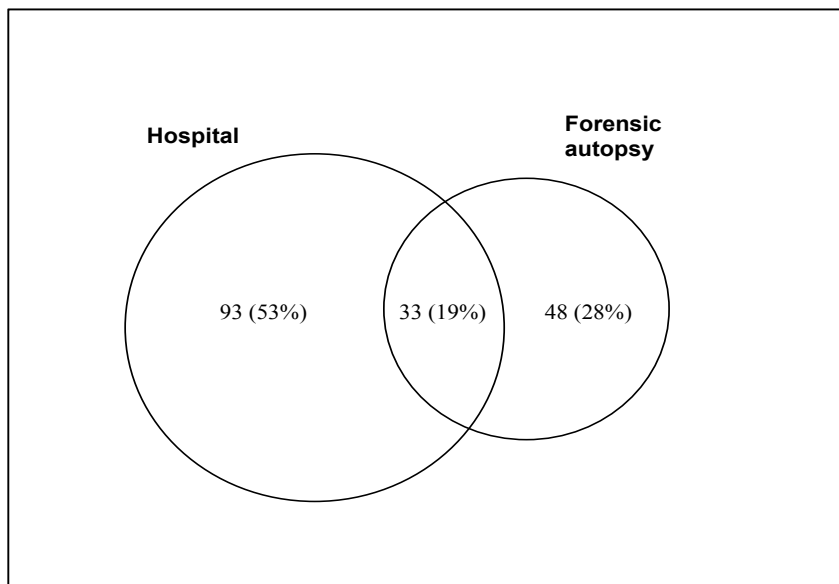


Figure 31.
Distribution of individuals with major trauma in Malmö.

Characteristics of cases first referred to hospital or for a medico-legal autopsy

Cases not admitted to hospital but sent directly for a medico-legal autopsy had a higher NISS score ($p<0.001$), and the proportion of children ($p=0.044$), accidents ($p<0.001$), and injuries caused by blunt trauma ($p<0.001$) was lower compared to cases admitted to the hospital. In contrast, the proportion of self-inflicted injury ($p<0.001$) and penetrating injury ($p=0.001$) was higher in cases sent directly for a medico-legal autopsy. Traffic accidents were sent to hospital first ($p<0.001$).

The time between trauma event and death could not be specified in days in seven fatalities. Among those admitted to hospital, 57% died within the first day.

Temporal distribution of trauma deaths in Malmö

Among 92 individuals, 48 (52%) died at the trauma scene (immediate deaths) and were sent directly to the Unit of Forensic Medicine for medico-legal autopsy. Twenty-eight (30%) patients arrived at hospital but died within one day after the injury (early deaths). Late deaths (>1 day of care) occurred in 16 (17%) patients.

Medico-legal autopsy and toxicology

Forty-eight (27.6%) out of 174 cases of major trauma were not first admitted to hospital and only identified at the Department of Forensic Medicine. Among all 81 trauma fatalities subjected to a medico-legal autopsy, 38% of the deaths were caused by accidents, 41% were suicides, and 21% were homicides. The median time between trauma and death was <1 day (range 0 - 16) in those 72 patients where it was possible to specify the time in days. Sixty-four (89%) of these patients died within the first day. The most prevalent drugs detected among the fatalities were ethanol (20%), sedatives (16%), anti-depressives (15%), and illicit narcotics (9%) (Table 6). The median ethanol concentration was 1.2‰ (range 0.14 - 2.87). Forty-four (54%) of the 81 trauma fatalities tested positive for at least one drug, and twenty-eight (35%) tested positive for two or more drugs at the medico-legal autopsy. The positive ethanol result in three out of 81 patients was considered to have been partially or fully formed by decomposition.

Table 6.

Results of medico-legal autopsy and toxicology examination after fatal major trauma in Malmö citizens between 2011 and 2013

Variable	N (%) of all eligible patients	N (%) of Accidents	N (%) of Suicides	N (%) of Homicides
All patients	81	31 (38)	33 (41)	17 (21)
Toxicology				
Alcohol (Ethanol)	16 (20)	6 (19)	8 (24)	2 (12)
Anti-depressives	12 (15)	4 (13)	7 (21)	1 (6)
Analgesics	8 (10)	3 (10)	3 (9)	2 (12)
Sedatives	13 (16)	6 (19)	7 (21)	0 (0)
Benzodiazepines	9 (11)	4 (13)	5 (15)	0 (0)
Zolpidem/Zopiklon	3 (4)	2 (6)	1 (3)	0 (0)
Theralen/Atarax	2 (2)	0 (0)	2 (6)	0 (0)
Propavan	1 (1)	0 (0)	1 (3)	0 (0)
Illicit drugs	7 (9)	3 (10)	3 (9)	1 (6)
Tetrahydrocannabinol	5 (6)	2 (6)	2 (6)	1 (6)
Amphetamines	3 (4)	3 (10)	0 (0)	0 (0)
Opioids	2 (2)	1 (3)	1 (3)	0 (0)
Psicolin (psychedelic mushrooms)	1 (1)	0 (0)	1 (3)	0 (0)
GHB (gamma-hydroxybutyric acid)	0 (0)	0 (0)	0 (0)	0 (0)
Cocaine metabolites	0 (0)	0 (0)	0 (0)	0 (0)
MDMA analogues (Methylenedioxymethamphetamine)	0 (0)	0 (0)	0 (0)	0 (0)

Hospital fatalities referred or not referred for medico-legal autopsy

A comparison was conducted of those hospital fatalities referred and not referred for medico-legal autopsy. Fatalities not subjected to a medico-legal autopsy were older ($p < 0.001$), had a lower NISS score ($p < 0.001$), had a longer duration of time between trauma and death ($p < 0.001$), and were more often subjected to fall accidents ($p = 0.030$) and to a surgical procedure ($p = 0.038$) during the admission. Fatal traffic accidents were to a larger extent sent to a medico-legal autopsy ($p = 0.043$). In the 11 cases not subjected to a medico-legal autopsy, nine cases had a fatal head injury and seven were more than 80 years of age. In two cases the police were contacted by the hospital staff and a medico-legal autopsy was not considered necessary. Furthermore, one person survived the trauma and died of a disease (cancer) unrelated to the trauma.

Comparison of medications in non-postmortem examined hospital fatalities due to fall accidents versus no-fall accidents

The number and type of medications among the 11 hospital fatalities that did not undergo medico-legal autopsy are shown in Table 7. The number of medications per individual were no higher in fall accidents than in no-fall accidents ($p = 0.16$). The Downton fall index was higher in the fall accident group compared to the non-fall accident group ($p = 0.024$).

Table 7.
Comparison between current medications in non-autopsied dead trauma patients injured due to fall accidents versus no-fall accidents

Variable	Fall accidents (n) (%)	No-fall accidents (n) (%)	P-value
Patients	7	4	
Medications			
Cardiovascular medications	6 (86)	1 (25)	0.88
Sedatives	6 (86)	1 (25)	0.88
Anti-hypertensive medications	5 (71)	1 (25)	0.24
Platelet aggregation inhibitors	4 (57)	2 (50)	1.0
Diuretics	3 (43)	0 (0)	0.24
Anti-epileptics	2 (29)	0 (0)	0.49
Median number of medications/individual (range)	8 (3-9)	4.5 (0-8)	0.16
Median Downton fall index (IQR)	4 (4.0-5.0)	2.5 (1.3-3.8)	0.024

Potential significant diagnostic errors as revealed by medico-legal autopsy

Thirty-three trauma deaths had received hospital care and were subjected to a medico-legal autopsy. Seventeen patients died at the trauma scene, during pre-hospital care, or during the very early stages of hospital care and were not subjected to trauma CT scan, whereas sixteen patients underwent both trauma CT and medico-legal autopsy. Thirty-six per cent of the organ injuries were diagnosed only by the radiologist, compared to 18% that were diagnosed only by the forensic pathologist (Table 8). Most disagreement was found in the head and thoracic part of the body. The medico-legal autopsy diagnosed two patients with fatty pulmonary embolism, which was not diagnosed by the radiologist or the clinician, and which was considered to have a direct impact on their fatal outcome. No other potentially significant diagnostic errors of importance for the fatal outcome were detected at autopsy.

Table 8. Agreement and disagreement in respect of diagnosed injuries between the radiologist and the forensic pathologist in the 16 eligible patients

Body region	Diagnosis obtained by both radiologist and forensic pathologist	Diagnosis obtained only by radiologist	Diagnosis obtained only by forensic pathologist	Total
Head	27 (63%)	11 (25%)	5 (12%)	43 (100%)
Thorax	22 (39%)	22 (39%)	12 (20%)	56 (100%)
Abdomen	9 (45%)	6 (30%)	5 (25%)	20 (100%)
Spine	8 (36%)	5 (23%)	9 (41%)	22 (100%)
Pelvis/Extremities	12 (60%)	4 (20%)	4 (20%)	20 (100%)
Skeleton	29 (46%)	15 (24%)	19 (30%)	63 (100%)
Organs	50 (46%)	39 (36%)	20 (18%)	109 (100%)

Death causes due to trauma in Malmö

The leading cause of death was intracranial injuries (38%; 35/92) among the 92 individuals who died after trauma. Deaths due to intracranial injuries were immediate in 86% (30/35), early (<1 day of care) in 6% (2/35), and late (>1 day of care) in 9% (3/35). Patients died due to bleeding and hypovolemic shock in 18% (16/92) and

thoracic injuries in 14% (13/92). Twelve (13%) patients died due to total body demolition, i.e. *corporis laceratio totalis*.

Of those 16 patients that died of hypovolemic shock, eight patients died in hospital and eight patients died at the trauma scene. In hospital, fatal bleeding injuries in major vessels were located in the thorax (n=6), thorax and abdomen (n= 1), and neck (n=1). At medicolegal autopsy, fatal bleeding injuries in major vessels were located in the thorax (n=4), thorax and abdomen (n= 1), neck (n=2), and extremities (n=1).

Figure 32 summarises the most common death causes due to trauma in Malmö.

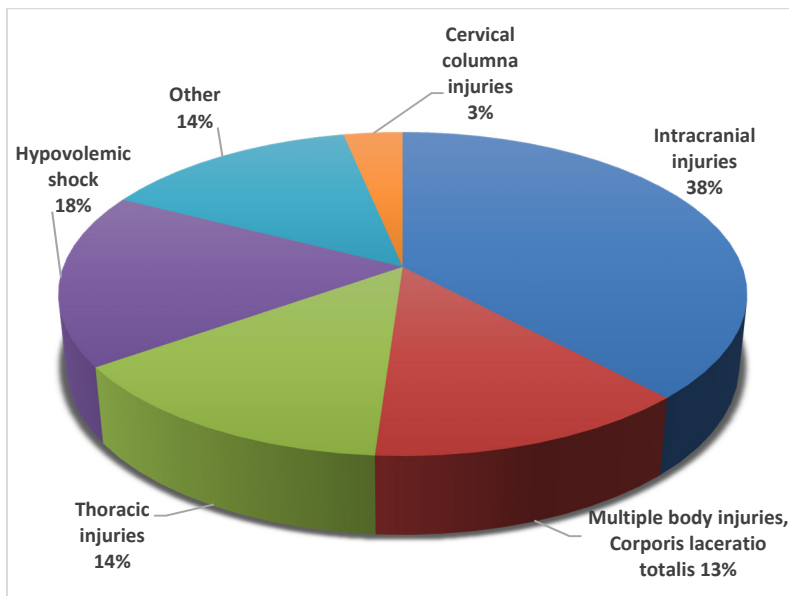


Figure 32. Death causes in all 92 trauma patients in the Malmö population.

General discussion

Population-based studies in trauma research

It is rare that trauma studies include both hospital and medico-legal autopsy data sets. The present thesis includes reports of medico-legal autopsies, which strengthens the accuracy of data retrieved in terms of better coverage of all major traumas and better performance in injury severity scoring when the medical charts or clinical investigations at hospital were incomplete. In particular, a complete autopsy provides a more reliable tool for documenting traumatic injuries than do clinical and radiological investigations alone (Sharma 2007).

The results of this thesis clearly show that a multi-disciplinary approach including data from both the clinical setting and medico-legal autopsies is necessary in order to correctly evaluate epidemiological data in major trauma.

Differences in available data on the incidence of major trauma

The global burden of injuries was studied in 2013 (Haagsma 2015), and the conclusion was drawn that about 973 million people in the world had sustained injuries requiring some kind of health care, resulting in a total global injury incidence rate of 461 per 100,000 person years. 4.8 million people died from their injuries: from traffic accidents (29.1%), self-inflicted injuries (17.6%), falls (11.6%), and interpersonal violence (8.5%).

The incidence of major trauma in the Malmö University Hospital catchment area was studied in *Study IV* and estimated as 14.5 (95% CI 12.1 - 16.9) / 100,000 person years. The incidence of medico-legal autopsy-verified individuals sustaining major trauma was 6.8 (95% CI 5.3 - 8.3) / 100,000 person years. In comparison, the incidence of fatal injuries verified at medico-legal autopsy in another Scandinavian population, that of northern Finland, was much higher: 54 (95% CI 51 - 56) deaths per 100,000 person years. Fatal injuries occurred more often in rural areas, where pre-hospital deaths were

more common. Almost half of pre-hospital deaths occurred under the influence of alcohol (Raatinemi 2016).

The mechanisms of injury in all major trauma were studied in *Study IV*, and the investigation showed that 59% (102/174) of these patients were injured due to unintentional causes (such as traffic accidents and falls) and 38% (66/174) due to intentional causes (homicides and suicides). In 3% (6/174) the causes of injury were unclear.

The summary report from the Victorian State Trauma Registry, Australia showed that, overall, 88.9% of major trauma patients sustained their injuries from accidental (unintentional) events. This is similar to the 86.6% reported for the United States (Victorian State Trauma Registry 2012). The incidence of individuals with major trauma in hospital and at medico-legal autopsy was five and three times higher than the respective incidence in *Study IV*. This might reflect differences in inclusion criteria, but nevertheless incidence and deaths due to major trauma were clearly higher in the state of Victoria. The in-hospital death percentage was lower and ex-hospital death percentage higher in Victoria, which might reflect differences in catchment areas and transportation systems.

In a country such as South Africa, which has one of the highest trauma rates in the world, the trauma incidence rates differ vastly from those of the Malmö population. The postmortem medico-legal reports from South Africa revealed that the age-standardised mortality rates for all injuries in 2009 were about 109 per 100,000 person years and that approximately half of all injury-related deaths were intentionally inflicted (homicide and suicide rates were 38.4 and 13.4 per 100,000 person years respectively) (Matzopoulos 2015). In that paper, the age-standardised mortality rate was 36.1 per 100,000 person years for road-traffic injury. In another South African study, the incidence of homicide in the year 2000 was shown to be 184 and 31.7 per 100,000 person years for males aged 15-29 and females aged 30-44 respectively, corresponding to nine and seven times the global rate (Norman 2007).

In South America's largest country, Brazil, the calculation for years of life lost in 2008 was shown to be 15-19 per 100,000 person years (depending on the part of the country), with homicide/violence (43%) the highest cause, followed by road-traffic accidents (31%). Falls accounted for the greatest share of years lived with disability (36%) (Campos 2015).

In Colombia the mortality rate in 2001 was shown to be 149 per 100,000 person years, and the rate of homicide was about three times higher than that of traffic accidents. The rate of reported homicide (60.8 per 100,000 person years) in 1995 was seven times as high as in the United States (8.3 per 100,000 person years) and more than 30 times as high as in Canada (1.8 per 100,000 person years) (Garfield 2004).

A recent published study from the United States has found that overall injury-related mortality rates have decreased, but with interesting differences in the mechanisms of mortality. Between 2002 and 2010, injury-related mortality caused by traffic accidents, falls, and gunshot decreased in the United States from 32.2 to 30.5 deaths per 100,000 individuals: the mortality rate for motor-vehicle traffic injuries decreased from 15.6 to 11.5 deaths per 100,000 individuals, whereas mortality rates increased for fall accidents during the same period, from 5.9 to 8.7 deaths per 100,000 individuals (Robert 2013).

Difficulties in performing clinical trauma research

Severely injured trauma patients are a difficult group to study. These patients are a very heterogeneous group of individuals with different mechanisms of injury. The highly stressful environment for the emergency services and hospital staff may have contributed to incomplete documentation, which was a particular challenge for us in *Study II*, and we faced major difficulties in collecting pre-hospital time intervals.

The retrospective study design of *Study II*, *Study III*, and *Study IV* was a limitation of the studies. The relatively few patients with major trauma from the respective districts in *Study I* made the results prone to statistical type 2 error. The lack of toxicological data on trauma survivors in *Study III* was a drawback in the retrospective design. Prospective trauma trials, however, require optimal organisation and staff dedicated to trauma protocols and research, and in such an environment, blood samples from trauma victims for toxicological screening should have a high priority.

Reproducibility of the New Injury Severity Scoring

The inter-rater reliability assessment of the NISS scoring used in this thesis showed that scoring was relatively more reliable among patients sustaining minor compared to major trauma, and that there was very strong agreement between rater's in respect of group allocation - i.e. major (NISS >15) or minor (NISS ≤15) trauma. The inter-rater reliability was tested to be satisfactory (ICC 0.83) among major trauma patients in the present study, whereas another study has reported unsatisfactory reliability results in 50 Norwegian major trauma patients with predominantly blunt trauma (Ringdahl 2013). The overall ICC value for the ten AIS-certified trauma registry rater's was 0.51, and only three rater's achieved an ICC value >0.7 when compared to the reference standard (Ringdahl 2013).

A regression analysis in the Ringdahl study showed a significant relationship between the number of correctly AIS-coded injuries and the rater's previous experience and the total number of cases coded before the actual rating. The authors of this study

(Ringdahl 2013) also speculated that missing injury information in patient charts and the possibility of injuries being described differently by radiologists and surgeons may have resulted in variability in coding and lower reproducibility results.

The fact that coding in this thesis was performed by only two rater's in *Study III* with similar coding and clinical experience in emergency medicine may have resulted in a relatively congruent, reliable coding.

The excellent results of the inter-rater reliability of the NISS scores among the medico-legal autopsies in *Study IV* make the comparative analysis between hospital admissions and medico-legal autopsies robust. As expected, the NISS scores were higher among trauma fatalities referred directly for medico-legal autopsy compared to the hospital admissions. The NISS scoring among rater's may diverge more in individuals sustaining major trauma than in individuals sustaining minor trauma, which is why it is important to include an inter-rater reliability assessment of the NISS score when using NISS as a predictive tool in outcome studies.

Differences in gender in trauma incidence

The higher rates of incidence and mortality due to trauma in men versus women shown in *Study I* reflect the fact that men are more exposed to trauma (Lozano 2012, Norman 2007). Globally, almost twice the number of males versus females are killed by injuries and violence and about three-quarters of all deaths from road-traffic injuries occur in men (Injuries and violence, WHO 2014). This could be explained by higher risk behaviour in men and the higher frequency of male drivers.

Socio-economic status as a risk factor for major trauma in Malmö

Income level and social assistance as a risk factor of major trauma

Study I showed that a lower income and need of social assistance within the household were associated with an increased risk of major trauma in Malmö, a Scandinavian city in a high-income country.

As shown in this thesis, it is important to include social assistance to households as a variable in epidemiological studies on socio-economic status. Social assistance reflects a low level of economic resources within a family, which may increase these individuals' vulnerability to mental illness, low self-confidence, and depression (Pickett 2015), and therefore their exposure to trauma.

Absence of level of education as a risk factor for major trauma

The absence of an association between educational level and major trauma in *Study I* may be attributed to the strictly district-matched control groups. A recent publication on major trauma patients in Stockholm, another city in Sweden, reported that a low level of education was an independent risk factor for trauma after a comparison with a municipality-matched control group (Brattström 2015). This discrepancy between the two studies reflects the importance of the selection of the control group. The place of residency appears to reflect socio-economic standards such as income and level of education to a large extent (City Office, Welfare accounting 2013; Injuries and violence 2014; SIRIS 2012).

In contrast to previous report (Brattström 2012, Borrell 2005), we observed no association between level of education and major trauma. We do recognise that *Study I* suffers from low statistical power when investigating education as a type of exposure for major trauma, due to the relatively low number of major trauma individuals studied. But we also used a different approach compared to previous studies (Brattström 2012, Borrell 2005), since our matching also included residential area. We speculate that our results indicate that education may have no separate effect on major trauma above and beyond that of residential area.

Socio-economic status varies widely among the city districts of Malmö, probably depending to a large extent on similar group togetherness and local culture within the same district, which have a strong unifying force among citizens with the same social background, and influencing their income as well as their health conditions (Ögren 2007). A lower SES in a district indicates that socio-economic factors such as poverty, overcrowded housing, less social fellowship, and a higher level of mental illness have a great impact on the educational level (Swedish National Institute of Public Health 2010, Engle 2008). Statistics from the Swedish national agency for education show that less than 30% of the children from the Rosengård district (the lowest WI in Malmö) have managed to meet the entry requirements for high school during the past five years, compared to 93% of the children from Limhamn-Bunkeflo district (one of the highest WIs in Malmö) (SIRIS 2012). Hence, we hypothesise that if we had not compared the cases in *Study I* with controls within the same district but with the entire municipality of Malmö, educational level would probably have been shown to be a significant risk factor for major trauma.

The association between pre-hospital times and mortality in Malmö

The “golden hour” (i.e. a total pre-hospital time of under 60 minutes) was not found to be a crucial factor predicting mortality in the Malmö trauma cohort, in contrast with other parts of the world where it has been considered to be a crucial factor in the management of trauma patients (Sampalis 2003). In a study from 2012 (Weiss 2012), trauma patients were studied at a trauma centre in the US, and, in line with *Study I*, longer response times were not associated with worse outcomes in terms of hospital stay, admissions, intensive care unit admissions, and mortality.

The longer total pre-hospital times observed in *Study II* for blunt injuries, such as from traffic accidents, as compared with times for penetrating injuries, might be the result of that most traffic accidents usually occurs on motorways or on roads with higher car speeds and often at long distances from the hospital, as well as the result of time-consuming rescue manoeuvres at the trauma scene. The shorter total pre-hospital times for penetrating injuries demonstrated in *Study II* might be explained by a shorter on-scene time and the occurrence of injuries in more central district areas of the city, nearer to the hospital and with short transport distances and less need of advanced life support at the trauma scene. Penetrating trauma such as gunshot wounds was also related to shorter on-scene times, which may partly explain the trend shown between shorter on-scene times and higher mortality found in *Study II*.

We speculate that EMS personnel, being aware that a short on-scene time is crucial for survival in the case of a penetrating injury (Funder 2011), have chosen to use a more strict adherence to the “load and go” principle due to the short transport distances to the hospital in Malmö.

Characteristics of trauma patients in Malmö

Investigating trauma scene addresses and the distribution of the individuals’ registration addresses in Malmö showed a high number of incidences of trauma in the centre of Malmö (Centrum) compared to the number of individuals living in that area, which probably could be explained by the normal daily migration of individuals from other districts into the city centre. However, about one-fifth of all trauma patients lived in two districts with high Welfare Indexes (*Study I*). *Study III* showed that 81% of all trauma in Malmö was from blunt injuries and 19% was from penetrating injuries. Blunt trauma is the most common type of trauma in European countries at 90%. This figure differs, though, from the data from the United States and South Africa, where penetration injuries constitute 20-45% and 60% of trauma injuries respectively (Champion 1990, Soreide 2009).

As shown in this study, traffic accidents were the most common cause of trauma in Malmö regardless of gender (*Study III*). *Study III* also showed that the median age was much higher for those with major trauma compared to patients sustaining minor trauma, at 45 and 27 respectively. The most frequently encountered age group in both genders was of individuals around 20 years of age. Among all individuals with major trauma in Malmö, almost half (53%) died, of which 11 patients (6%) did not undergo medico-legal autopsy (*Study IV*). Nearly one-third of patients who suffered major trauma died before admission to hospital (*Study IV*).

Injury severity, age, and physiological variables predicting survival

The NISS scoring system is an established model for predicting survival in patients after trauma (Eid 2015, Belzunegui 2013).

In *Study III*, the results showed that a NISS score up to 24 seemed to be associated with low mortality, or around 2% as demonstrated in previous studies (Jones 2014), whereas mortality increased markedly with higher NISS scores. The NISS score was expected to be associated with mortality. In *Study III*, however, the unchanged mortality rate among patients with an NISS score of 16 - 24 as compared to those with an NISS score of 9 - 15 questions the definition of the border between major and minor trauma. When the NISS score was 25 or higher, though, the mortality rate increased dramatically.

Overall NISS score, serious head and neck, thorax, and abdomen injury, shock on admission, and age were factors associated with mortality in a univariate analysis (*Study III*). To a varying extent these factors reflect anatomic injury, physiologic reserve, and age, which have been proven to effectively predict trauma mortality in a Scandinavian population with its typical spectrum of injury mechanisms (Jones 2014).

The use of radiology in trauma diagnostics

CT scanning was used in 80% of major trauma patients, which actually not was, statistically, lower in minor trauma patients, 72%. The protocol for trauma CT, however, was used twice as often in major trauma cases, i.e. 64% versus 35% respectively. Of note, children with major trauma in this study also underwent CT scanning in the same proportion (80%). The data perhaps indicates an overuse of CT scanners by clinicians due to the great availability of this fast, high-resolution imaging modality. Recently, a study by Pandit et al. (Pandit 2015) showed that children

managed in adult trauma centres were more likely to undergo trauma CT, increasing their exposure to risk from radiation without any difference in outcomes. Concerns have been raised over exposure to unnecessary radiation and its long-term effects. A great number of trauma survivors may indeed suffer consequences of radiation exposure and have an increased risk of fatal cancer over the long term (Beatty 2015). According to Beatty et al., the mean whole-body radiation exposure for all trauma patients in their study was so high that it could be correlated to one additional cancer death for every 100 trauma patients scanned.

Fall accidents among the elderly

A longer on-scene time and total pre-hospital time were found among elderly patients in *Study II*. One explanation could be that older people to a larger extent suffer from comorbidities and may have difficulties mobilising, especially in trauma situations. We noted that 55% of patients aged 65 years or more had major trauma injuries, compared to 27% among those less than 65 years of age, probably contributing to prolonged on-scene times and perhaps more advanced on-scene interventions. However, *Study II* could not demonstrate that injury severity was associated with prolonged pre-hospital time intervals.

The results from *Study III* showed that 28 (58%) of the 48 elderly patients were involved in fall accidents. Overall, fall accidents are the second most common cause of trauma-related death in the world (Injuries and violence 2014). The finding of a high prevalence of fall accidents among the elderly has important implications for prevention. Efforts should be made, for example, to improve walking devices for the elderly, to better adapt the homes of the elderly for their living situations, to prevent dizziness and orthostatic hypotension, and to have a dedicated doctor recurrently reviewing the number and sort of the patient's medications. The number of medications taken by the elderly probably has an influence on the occurrence of trauma in the elderly (Rosendahl 2003), especially fall accidents. After a complementary search for data in *Study IV*, the number of medications found among fatal fall accident patients who did not undergo medico-legal autopsy clearly shows that these elderly patients were under the influence of pharmacological agents at the time point of the accident. In this small comparative series (Table 7), the number of medications was not higher in the fatal fall accident group compared to the fatal non-fall accident group, which most likely is a result of a type 2 statistical error. Nevertheless, the calculated Downton fall index was found to be a strong discriminator between these two groups and the Downton fall index was higher in the fall accident group. Therefore, widespread awareness within geriatric care of the

composition of the factors in the Downton fall index seems to be very important for preventive work against fall injuries among the elderly.

One retrospective study has investigated the comorbidity-polypharmacy score, which is the sum of all pre-injury medications and comorbidities, and has found that the score is an independent predictor of all-cause morbidity and mortality in older trauma patients (Mubang 2015). Large prospective surveys studying polypharmacy as a risk factor for trauma are, to our knowledge, absent in the literature. Perhaps such a study including the medico-legal autopsies of all elderly fatalities due to suspected trauma would reveal a significant effect from polypharmacy on death in fall accidents. In the United States the patterns of trauma-related mortality have largely changed during the last decade. Better safety in cars, the general public's better knowledge of safety, and better health-care systems have resulted in lower mortality rates caused by traffic accidents, but an increasingly elderly population has increased the mortality rates in fall-related injuries, partly due to the fact that falls are exponentially associated with older age (Robert 2013).

The presence of post-traumatic infections in trauma studies

Severe infections and sepsis are major contributors to morbidity and delayed hospital mortality in trauma patients, and early prediction of and intervention in the development of sepsis can therefore improve outcomes (He Jin 2014). In one trauma population studied in an ICU (Brattström 2010), one-third of the patients developed severe sepsis, with an impact on their ICU stay and mortality. The overall rate of post-traumatic infection has not been studied in the present population-based studies (*Study III* and *Study IV*), but in *Study IV* we found that post-traumatic infections were much more common in hospital fatalities (55%) not referred for a medico-legal autopsy, reflecting a longer in-hospital stay and survival after injury with the possibility of developing an infection, whereas the percentage of trauma-related infections at medico-legal autopsy was very low (3%). Regardless, the rationale for antibiotic prophylaxis in major trauma was recently evaluated in a systematic review (Poole 2014), which found that antibiotic prophylaxis may be indicated in the prevention of early ventilator-associated pneumonia in comatose patients with traumatic injury, while the risk of selection of resistant-bacteria caused by antibiotic administration for more than two days actually outweighed potential benefits.

Toxicological findings in lethal trauma

A large proportion (54%) of individuals subjected to a medico-legal autopsy toxicology screening tested positive. The high positive toxicology rate among fatalities has implications for the prevention of future trauma, not only in trauma survivors but in the whole population from a long-term perspective.

As most of the trauma-related deaths in *Study III* and *Study IV* occurred within the first day, forensic toxicology data should be very useful, since drug clearance from blood circulation most likely has not occurred completely in most patients. The substances detected, whether illicit or not, may be of great value in identifying socio-economic factors and circumstances so as to better understand the risk factors associated with major trauma in the population studied, which in turn may be of use for better clinical management and for prevention of trauma. Previous, larger medico-legal autopsy series in Sweden have shown that a large proportion of fatal traffic accidents, falls, and homicides tested positive for ethanol in the blood (Sjögren 2006), particularly among men, and that the violent suicide method of jumping from a height was related to finding the illicit drug, tetrahydrocannabinol (Lundholm 2014). It is unclear whether there is a difference in the proportion of psychotropic drugs among individuals with fatal versus non-fatal trauma, as to date there are no population-based studies available analysing this issue. It cannot be excluded that the anti-depressives, sedatives, and analgesics detected in some patients might have been taken for medical reasons and used in proper doses. Nevertheless, the toxicological results may imply that some patients suffered from certain diseases or conditions, such as depression, anxiety, insomnia, or abuse, which is of importance in the occurrence of trauma. There are very few prospective studies analysing the prevalence of drugs in trauma survivors, but available data from urine toxicology screenings suggests that drug use is widespread in patients presenting with a moderate injury at an urban trauma centre (Figl 2010) or after road accidents (Ricci 2008).

Importance of including medico-legal autopsy data

In terms of overall incidence and mortality data, *Study IV* has clearly shown that such epidemiological surveys are dependent on both hospital and medico-legal data. Most importantly, comparisons of injury-related deaths between countries are dependent on medico-legal autopsy rates (Lunetta 2007). Furthermore, *Study IV* shows that individuals admitted to hospital and those who died at the trauma scene and were sent directly for a medico-legal autopsy differed in a number of characteristics. A higher proportion of penetrating trauma was encountered among individuals sent directly from the trauma site to the Department of Forensic Medicine. All individuals involved

in traffic accidents were initially admitted to hospital, which might be explained by the short transportation times to the Emergency Department. The rate of fatal injuries admitted to hospital is lower in the northern parts of Sweden and Finland, where the catchment areas are geographically larger (Ahlm 2009, Raatinieniemi 2016).

In Sweden (Rammer 2011), as well as in many other countries around the world (Charles 2007, Steinwall 2012), deaths due to trauma are considered unnatural and legal provisions require that all unnatural deaths be reported to the legal authorities for a decision on whether to conduct a medico-legal postmortem examination. All 11 of the patients identified in *Study III* and *Study IV* that sustained major trauma and died but were never sent for medico-legal examination may have been managed erroneously by the responsible physicians and/or the police authority.

It is known that nursing home deaths which fall under the jurisdiction of the coroner seldom undergo medico-legal autopsy in the United States (Lindner 2007), and that a similar situation exists in Sweden (Pettersson 2014). In one report, blunt force trauma was found to be a major autopsy finding (58%) in accidental nursing home deaths (Lindner 2007). In the state of Victoria, Australia, only 38% of reportable in-hospital deaths that met the coroner's reporting criterion were actually reported to the coroner (Charles 2007).

Empirical evidence of post-traumatic medico-legal autopsy data has revealed the extent to which underreporting compromises the evaluation of violence and injuries, suggesting that reports from the Forensic Department could improve estimates of mortality from external causes and complement national/global trauma data (Matzopoulos 2015, Lunetta 2007).

A better adaptation to the international forensic laws on medico-legal autopsy might improve the detection of preventable causes of deaths in the elderly with suspected or witnessed trauma.

In addition, a multi-disciplinary research strategy is necessary across disciplines and registries so as to gain more information on, for instance, polypharmacy and fall mechanisms in order to be able to work on preventive measures.

Temporal distribution of trauma deaths

The temporal distribution of trauma deaths in Malmö was similar to the distributions reported in the papers by Trunkey (Trunkey 1983) and Demetriades (Demetriades 2005). Although the time in hours between injury and death of the individuals was not accurately recorded in *Study IV*, it was possible to obtain extrapolations of good estimates of the proportions of immediate, early, and late deaths. Patients who died at the trauma scene and were sent for medico-legal autopsy were assumed to have died

immediately, although the time intervals between trauma and death were unknown in a few patients. It was therefore possible to extrapolate good estimates and the proportion of immediate deaths (52%) might have been slightly underestimated, since all individuals involved in high-speed traffic accidents were brought to hospital and a few of them were actually declared dead on arrival. The bimodal, immediate, and early phase distribution of trauma deaths as postulated by Demetriades (Demetriades 2005) is in line with the findings in *Study IV*. The results in *Study IV* strengthen the view that the proportion of immediate deaths (around 50%) remains high and unchanged (Trunkey 1983, Demetriades 2005), which strongly emphasises the importance of trauma prevention programmes such as those directed at firearm violence, drink driving, seat belt and airbag use, and illegal drug use.

Potentially preventable trauma deaths

In the population-based study of major trauma patients in *Study IV*, a proportion of patients could not have survived, a proportion are highly likely not to have been able to survive, and a proportion potentially could have survived. Patients with total body demolition and the majority of intracranial injuries were unsurvivable. Intracranial injuries were the leading cause of trauma death in Malmö; a large study conducted in the western part of the United States reported similar findings (Acosta 1998). Major vessel injuries in the thorax accounted for 75% (12/16) of trauma deaths due to bleeding in *Study IV*. Patients dying from thoracic injuries and/or hypovolemic shock due to bleeding are the ones most likely to be able to be rescued with optimal trauma organisation to stop bleeding and with immediate access to an operation theatre for prompt surgical management and damage control (Demetriades 2005, Rossaint 2010).

Future perspectives

Prevention of trauma requires awareness of the risks connected with susceptibility to injuries, including a knowledge of the common denominators in districts with lower SES, such as low income, need of social assistance, individuals with health problems, and a higher likelihood of trauma.

We believe that more studies are needed to investigate the effects of educational level in patients living in the same residential area and in the risk of major trauma in other countries.

To further evaluate pre-hospital trauma care we suggest a prospective study where the EMS trauma scoring (Lerner 2003) at the trauma scene is compared to NISS scoring in hospital in order to predict mortality. It might be that EMS trauma scoring is a better pre-hospital prognostic tool than pre-hospital rescue times, and may dictate better life-saving management at the trauma scene.

The results of *Study III* and *Study IV* suggest that routine screening for drugs in the Emergency Department would be worthwhile in order to study whether the proportion of drug prevalence is similar among trauma survivors with less severe injuries. If such a study should show a high percentage of drug positivity among trauma-related patients, the set-up of a follow-up management algorithm may be facilitated and supported by the health-care system. It has been suggested that in patients testing positive for drugs, brief interventions can help to prevent future trauma (Nicholson 2014). In addition, it is highly valuable for the physician in charge to be aware of any drug positivity when assessing alertness in a multi-trauma patient, for instance, or to avoid undesired effects when administering pharmaceuticals at the induction stage of anaesthesia in a patient in need of surgery.

The negligence or lack of knowledge of physicians and/or the police authority in respect of referring patients who have died due to trauma for a medico-legal autopsy has recently been brought to the attention of the *Swedish Medical Journal* (Onaturliga dödsfall, Pettersson 2014). In an attempt to improve the quality of death certificates in Sweden, it has been suggested that the appearance of the death certificate should be changed so as to more clearly state that if a death has not been caused exclusively by a natural disease, the police authorities must be notified by the physician signing the certificate (Handläggning av dödsfall, Pettersson 2014). If coroners are to optimise their

potential to contribute to public health and safety, doctors reporting deaths must understand which deaths are reportable.

Multi-disciplinary research strategies should be encouraged. Based on the results of the present thesis, focused research on falls in the elderly and on the influence of polypharmacy seems to be warranted, as is collaboration across specialities and registries.

Conclusions

- Low income and social assistance within households were associated with major trauma in the city of Malmö, whereas level of education was not.
- Pre-hospital rescue times had less impact on mortality than did injury severity, age, and penetrating trauma. Even though penetrating trauma was associated with shorter on-scene times and a shorter transport distance to hospital, mortality was increased in this Scandinavian urban setting.
- The high proportion of positive toxicological findings at medico-legal autopsy implies that toxicology screening should be routine in major trauma patients in order to be able to intervene and prevent future trauma in survivors.
- Nearly half of the individuals sustaining major trauma died. The negligence or lack of knowledge of the physicians and/or the police authority in respect of referring trauma patients for a medico-legal autopsy resulted in 25% of all in-hospital trauma-related death not undergoing medico-legal autopsy. These patients were often older, had suffered from fall injuries, had intracranial injuries, and were treated longer in hospital.

Populärvetenskaplig sammanfattning

Malmöns befolkning har under senaste åren nästan dagligen i media blivit påmind om den alltför vanliga förekomsten av olyckor och våld i Malmö. Men hur ofta drabbas Malmöbor av olyckor eller självmord? Och hur går det för de överlevande ?

En forskning inom våld och trauma har därför ansetts vara högaktuell i Malmö för att kunna kartlägga hur pass allvarliga skador vi har, vilka risk faktorer som är relaterade till trauma och hur det går för dessa personer efter ankomsten av ambulans till skadeplatsen och senare vård på sjukhuset. Obduktions rapporter på avlidna avslöjar också hur många av all onaturliga död i Malmö som faktiskt aldrig har inkommit till sjukhuset och dött momentant på skadeplatsen och vilka droger/mediciner alla obducerade trauma fall har exponerats för innan döden. Utifrån dessa data kan man få en liten glimt av hur dessa personer sista dagar här i livet har sett ut.

Svar på dessa frågor är efterlängtade och väcker stort intresse både bland vårdpersonal och våra politiker.

Det är ovanligt att epidemiologiska studier av patienter med allvarliga trauma inkluderar både patienter som blivit handlagda på sjukhuset och de som dött på skadeplats och genomgått rättsmedicinsk obduktion. I denna avhandling ansåg vi detta vara en förutsättning och det var därför viktigt att slå ihop dessa två register för att få en så sann bild av verkligheten som möjligt.

I denna avhandling identifierades ”allvarliga” traumafall enligt trauma-poängskalan New injury severity score (NISS) >15. I *Studie IV* inkluderades även personer som dött av trauma och som enbart registrerades vid Rättsmedicinska Institutionen. Patienter som drabbades av drunkning, hängning, stopp i luftvägarna eller enbart brännskada exkluderades från alla våra studier enligt gällande riktlinjer för definitionen av trauma i Europa. Trauma inom Malmöområdet mellan den 1 januari 2011 och den 31 december 2013 identifierades via en databas som inkluderade alla röda larm på akutmottagningen och intensivvårdsavdelningen vid Skånes Universitetssjukhus, Malmö, samt från en databas med alla patient fall som obducerats vid Rättsmedicinalverkets avdelning i Lund.

Det har under de senaste decennierna gjorts stora insatser för att förbättra personal kompetensen och kvalitén på den tekniska utrustningen inom ambulanssjukvården.

Det finns till idag en rad olika internationella studier där man har undersökt om det är bättre att omedelbart transportera den skadade patienten till sjukhuset efter trauma eller om det är bättre att stanna kvar en stund på skadeplatsen för att stabilisera patienten först och sedan transportera patienten till sjukhuset.

Det finns nämligen en allmän uppfattning om att utfallet efter en skada förbättras om den totala utanför-sjukhus tiden är så kort som möjlig. En utanför-sjukhus tid på mindre än 60 minuter, den så kallade "gyllene timmen", har under lång tid betraktats som ett accepterat mål för att hålla god kvalitet på traumasjukvården i städerna. Svarstiden, det vill säga tiden mellan ett telefonsamtal till SOS larmtjänst och ambulans ankomst till skadeplatsen, har också ansetts vara ett viktigt mått på ambulansvårdens kvalitet. En svarstid som är mindre än 8 minuter har rapporterats vara förknippad med en bättre överlevnad. Studier om räddningstidens betydelse för dödligheten i förhållande till skadornas svårighetsgrad har undersökts i andra delar av världen, men sällan i de skandinaviska städerna.

I *Studie I* inkluderades endast allvarliga trauma fall med folkbokföringsadress i Malmö. I denna studie matchade Statistiska centralbyrån fallen med fyra slumpmässigt ålders, köns- och stadsdelsmatchade kontroller. Utbildningsnivå, inkomst, kapitalinkomst och socialbidragsbehov i familjen jämfördes i en fall-kontroll analys.

Resultatet från *Studie I* visade att median åldern för allvarligt trauma i Malmö låg på 48.0 år. Incidensen allvarliga trauma i Malmö var 12.7 / 100 000 person år. Kontroll matchningen från denna studie visade enhetligt att låg inkomst, och socialbidrag i hushållet var associerat med allvarligt trauma, men dock inte utbildningsnivån, vilket var överraskande, men där betydelsen av boende i en viss stadsdel sannolikt var viktigare än utbildningsnivån för uppkomsten av allvarligt trauma.

Studie II visade att 89% procent av patienterna som skadats till följd av ett trauma erhöll sjukhusvård inom 60 minuter. Hos 51% förekom en svarstid på ≤ 8 minuter och 95% hade fått ambulanshjälp inom ≤ 20 minuter. Patienter med penetrerande skador såsom skottskador hade en kortare vård tid på skadeplatsen jämfört med dem som skadats med trubbigt våld. Det fanns också en trend i våra resultat att förekomsten av skottskador var associerad med ökad dödlighet vilket därför kunde förklara sambandet mellan fyndet kort handläggningstid på skadeplatsen och den höga dödligheten.

Vi fann en längre total-utanför-sjukhus tid vid trubbiga skador såsom vid trafikolyckor, jämfört med penetrerande skador, vilket kan vara ett resultat av att de flesta trafikolyckor inträffar på motorvägar eller vägar med högre bil hastighet och därmed oftare längre avstånd till sjukhuset. Den kortare total-utanför-sjukhus tiden vid penetrerande skador kan troligtvis förklaras av dels en kortare handläggningstid på skadeplatsen men dels också pga penetrerande våld oftare förekom i de mera centrala distrikten i staden, närmare sjukhuset, och därmed också kortare transportsträckor och mindre behov av avancerade livsuppehållande insatser på skadeplatsen.

I *Studie III* studerades all förekommen trauma deskriptivt i Malmö samt den akuta handläggningen undersöktes i detalj på sjukhuset såsom röntgen undersökningar, operationer och vård på sjukhusets intensivvårdsenhet. Denna studie påvisade att det förekom 125 fall av allvarliga och 303 fall med mindre allvarliga trauman i Malmö under tre års tid. Trafik och fallolyckor var de ledande mekanismerna av skador. Äldre (≥ 65 år) hade en ökad risk för fallolyckor. Tre-månaders dödligheten var 10,3%. Skador med högre NISS poäng, högre ålder och massiv blodtransfusion var förknippade med ökad dödlighet. Trettio tre patienter, av totalt 44 döda, genomgick rättsmedicinsk obduktion och 52% av dessa fall var positiva för minst en drog/läkemedel i kroppen. Efter genomgång av analyserna på rättsmedicinalverket kunde vi också konstatera att de vanligaste drogerna/läkemedel som hittades vid obduktionerna var etanol (15%), anti-depressiva (15%) och lugnande (12%) läkemedel. Hos 12 % kunde man hitta någon form av narkotika.

Fokus under *Studie IV* låg på att med denna studie undersöka betydelsen av att inkludera rättsmedicinskt obducerade fall i studier av allvarliga trauman. Enligt svensk lagstiftning skall alla trauma-relaterade dödsfall rapporteras till Polisen för hänvisning till rättsmedicinsk obduktion. Resultatet från denna studie visade att 174 individer drabbades av allvarligt trauma, av vilka 53% hade dött. Ett hundratjugosex patienter identifierades på sjukhuset och 48 transporterades direkt från skadeplats till rättsmedicinsk undersökning. Av de som anlände till sjukhuset dog fyrtio fyra patienter, och av dessa genomgick endast 75% rättsmedicinsk undersökning. Av de individer som var avlidna på skadeplatsen och ej passerade sjukhuset men genomgick rättsmedicinsk obduktion, var proportionen av olyckor lägre, självtillfogade skador högre och skottskador högre i jämförelse med de som initialt hamnade på sjukhuset. Faktorer som var associerade med en lägre frekvens av rättsmedicinsk obduktion i studiepopulationen var högre ålder, lägre allvarlighetsgrad av skador samt förekomsten av fallolyckor.

Slutsatsen av denna avhandling kan kort sammanfattas i att låg inkomst och socialbidragsbehov i hushållet är förenat med allvarligt trauma i Malmö, men dock inte utbildningsnivån.

Den "gyllene timmen" eller svarstid under 8 minuter tycktes inte vara avgörande faktorer för att förutsäga dödlighet efter trauma i Malmö.

För att bättre utvärdera utanför-sjukhus tidens betydelse för utfallet av skadade patienter, föreslår vi att man i framtida studier undersöker ambulanspersonalens bedömning av skadans allvarlighetsgrad på skadeplatsen. Det kanske kan visa sig att ambulans personalens bedömning av skadans allvarlighetsgrad kan vara ett bättre prognostisk mått än räddningstiden för att kunna förutsäga utfallet. Framför allt bör sambandet mellan på-skadeplats tid och ambulansens skadebedömning vara av intresse att utvärdera.

Vi kunde också påvisa att när man studerar våld och trauma i befolkningen, i sin helhet, är det viktigt att samla in data från både sjukhuset och rättsmedicinalverket. En sådan analys har i våra studier inte bara visat att mer än hälften av alla individer som drabbats av allvarliga trauma har dött till följd av sina skador, men också att många av dessa också har haft någon form av drog eller läkemedel i kroppen som kan antyda en livsleda och/eller funktionssänkning innan skadetillfället. Denna höga andel toxikologiska fynd bland de rättsmedicinskt obducerade fallen indikerar att toxikologisk screening borde bli rutin på alla akutmottagningar vid allvarliga trauma, dels för vården av den skadade och dels som led i prevention av framtida trauma inom populationen.

Ytterligare 25% av alla trauma relaterade dödsfall på sjukhuset borde enligt svensk lagstiftning blivit föremål för rättsmedicinsk obduktion.

Det är av yttersta vikt att vårdpersonal och politiker i samhället identifierar risk faktorerna till trauma och försöker sätta in åtgärder så att livet hos dessa personer inte behöver sluta i förtid. Ett samarbete mellan vår forskningsgrupp och akutkliniken på sjukhuset i Malmö pågår just nu för att implementera blodanalyser för droger/läkemedel på alla allvarliga trauma fall för att identifiera de som har en ökad risk att återfalla i trauma.

متن علمی خلاصه شده به زبان ساده

در باره وقوع بیش از حد معمول حوادث و خشونت در شهر مالمو تقریباً هر روزه از راه رسانه ها در این سال‌های گذشته به اهالی مالمو یادآوری شده است. اما در چه بازه‌های زمانی مردم این شهر از حوادث و خودکشی رنج می‌برند؟ و بر جان بهر بردگان چه می‌گذرد؟

به همین خاطر به نظر می‌رسد که برای شناسایی میزان شدت آسیب‌های جدی که ما داریم و شناخت عوامل خطر مرتبط با این تروما و این که پس از آمدن آمبولانس به محل وقوع حادثه و پس از آن در بیمارستان بر این افراد چه می‌گذرد انجام تحقیقی در باره خشونت و تروما در مالمو مسئله روز باشد. گزارش‌های کالبدشکافی درگذشتگان همچنین آشکار می‌سازد که چه تعداد از این مرگ‌های غیر طبیعی در مالمو که هرگز به بیمارستان هم کشیده نشده و در همان محل حادثه رخ داده است و یا مرگ همه آن‌هایی که کالبدشکافی شده اند در اثر چه نوع مواد مخدر یا دارویی اتفاق افتاده و این که همه موارد کالبد شکافی شده ترومای پیش از وقوع مرگ را نشان می‌دهد. بر اساس این داده‌ها می‌توان به یک نگاه اجمالی از چگونگی روزهای پایانی زندگی این افراد دست یافت.

پاسخ به این پرسش‌ها مورد علاقه کارکنان بخش درمانی همچنین سیاستمداران ما بوده و توجه زیاد آن‌ها را برمی‌انگیزد. انجام مطالعات همه‌گیرشناسی در مورد بیماران با ترومای شدید که شامل هم بیمارانی که در بیمارستان تحت مراقبت قرار گرفته‌اند و هم بیمارانی شود که در محل حادثه در گذشته‌اند و در پزشکی قانونی کالبدشکافی می‌شوند امری نادر است. در این گزارش پژوهشی ما فرض را بر این گذاشتیم که این یک پیش‌نیاز است و به همین دلیل این دو لیست را در هم ادغام کردیم تا در حد امکان یک تصویر حقیقی از واقعیتی که وجود دارد به دست آوریم.

این گزارش پژوهشی ترومای «شدید» را مطابق درجه‌بندی صدماتِ New Injury Severity (NISS) source بیشتر از رتبه ۱۵ قرار داده است. بررسی شماره ۴ کسانی را هم که در اثر تروما در گذشته‌اند و تنها نامشان در دفتر انسیتیو پزشکی قانونی ثبت شده است را نیز در بر می‌گیرد. بیمارانی با مصدومیت‌های ناشی از غرق شدن، حلق‌آویز شدن، خفگی یا تنها سوختگی بنا بر دستورالعمل جاری برای شناسایی تروما در اروپا بیرون از همه پژوهش‌های ما قرار دارند.

تروما در منطقه مالمو از اول ژانویه ۲۰۱۱ تا ۳۱ دسامبر ۲۰۱۳ که در یک بانک اطلاعاتی کامپیوتری شناسایی شده است، شامل همه وضعیت‌های اضطراری در پذیرش‌های اورژانس و بخش‌های مراقبت‌های ویژه در بیمارستان‌های دانشگاه اسکونه، مالمو همچنین داده‌های بانک اطلاعاتی کامپیوتری همه بیمارانی که در بخش پزشکی قانونی در شهر لوند کالبدشکافی شده‌اند، می‌باشد.

در طول دهه‌های اخیر سرمایه‌گذاری‌های بزرگی برای بالابردن توانایی‌های کاری کارکنان و کیفیت تجهیزات فنی در مراقبت‌های پزشکی در آمبولانس صورت گرفته است.

تا به امروز یک رشته پژوهش‌های گوناگون بین‌المللی در این باره انجام شده که آیا بهتر است بیمار مصدوم بلادرنگ به بیمارستان حمل شود یا بهتر است به منظور ثابت شدن وضعیت بیمار اندک مدتی در محل وقوع حادثه باقی بماند، سپس به بیمارستان حمل شود.

در واقع یک برداشت همگانی وجود دارد که هر چه مدت زمان پیش از رسیدن بیمار به بیمارستان کاهش یابد عوارض پس از مصدومیت نیز کاهش می‌یابد. مدت زمان کمتر از ۶۰ دقیقه بیرون از بیمارستان بودن، به اصطلاح «زمان طلایی» برای دوره‌های طولانی هدف قابل پذیرشی برای حفظ کیفیت خوب در امر مراقبت‌های پزشکی مصدومین در شهرها به حساب می‌آید. مدت زمان پاسخ، یعنی مدت زمان بین یک تماس تلفنی با مرکز خدمات کم‌کسانی اورژانس تا آمدن آمبولانس به محل حادثه معیار مهمی برای سنجش کیفیت خدمات حمل بیمار در نظر گرفته شده است. ارتباط بین یک مدت زمان پاسخ ۸ دقیقه ای با امکان بیشتر زنده ماندن گزارش شده است. مطالعاتی در باره اهمیت مدت زمان عملیات نجات و رابطه آن با مرگ و میرهای ناشی از مصدومیت‌های شدید در جاهای دیگر جهان انجام شده اما این‌گونه مطالعات در شهرهای اسکانديناوی به ندرت صورت گرفته است.

پژوهش شماره ۱ تنها موارد ترومای شدید افرادی که درنشانی‌های ثبت شده در شهر مالمو هستند را شامل می‌شود. در این پژوهش مواردی از اداره مرکزی آمار با چهار گزینه توافقی: سن، جنس و منطقه شهری کنترل می‌شود. میزان تحصیلات، در آمد از کار، در آمد از سرمایه و نیاز به کمک‌های مالی در خانواده در مقایسه با یک مورد انتخابی به منظور کنترل مورد تجزیه و تحلیل قرار گرفته است.

نتیجه پژوهش شماره یک نشان داد که متوسط سن برای ترومای شدید در مالمو ۴۸ سال است. میزان وقوع آن در مالمو ۱۲،۷ نفر در ۱۰۰،۰۰۰ نفر در سال است. مطابقت کنترلی داده‌های این پژوهش به طور یکپارچه نشان داد که در آمد پایین و کمک مالی برای اداره امور خانه تداعی کننده تروما است، اما میزان تحصیلات به طور غیر منتظره‌ای چنین نبود؛ در جایی که اهمیت محل زندگی در بخش معینی از شهر احتمالاً از میزان تحصیلات در وقوع تروما از اهمیت بیشتری برخوردار بود.

پژوهش شماره ۲ نشان داد که ۸۹٪ بیماران که در اثر تروما دچار آسیب‌دیدگی شده‌اند مراقبت‌های بیمارستانی را در ظرف ۶۰ دقیقه دریافت نموده‌اند. در ۵۱٪ مورد مدت زمان پاسخ حدود ۸ دقیقه یا کمتر طول کشیده و ۹۵٪ ظرف ۲۰ دقیقه یا کمتر از کمک آمبولانس برخوردار شده بودند. بیماران با جراحات عمقی مانند جراحات ناشی از گلوله، مراقبت پزشکی کوتاه‌مدت تری در مقایسه با جراحات در اثر خشونت (ترومای بلانت) در محل حادثه دریافت نموده‌اند. همچنین در نتیجه‌گیری ما روندی مشاهده شد که وقوع جراحات ناشی از گلوله، با افزایش مرگ و میر پیوند داشت که این امر می‌توانست توضیح‌دهنده رابطه بین بررسی کوتاه مدت تر در محل وقوع حادثه با میزان مرگ و میر بالا داشته باشد.

ما همچنین دریافتیم که زمان طولانی‌تر مراقبت‌های پیش از بیمارستان در مورد جراحات ناشی از خشونت و حوادث رانندگی در مقایسه با جراحات عمقی می‌تواند در نتیجه این باشد که اغلب حوادث رانندگی در بزرگراه‌ها یا در جاده‌های با سرعت مجاز بالا رخ می‌دهد که اغلب فاصله زیادی با بیمارستان دارند. مراقبت پزشکی کوتاه مدت تر در بیرون از بیمارستان در مورد جراحات عمیق می‌تواند چنین توضیح داده شود که احتمالاً بخشی به خاطر مدت زمان کوتاه مراقبت پزشکی در محل باشد، و بخشی هم به این دلیل باشد که این‌گونه صدمات اغلب در نزدیکترین جاها به

مرکز شهر به وقوع می‌پیوندند که به بیمارستان هم نزدیک‌ترند و بدین ترتیب مسافت تا بیمارستان کوتاه‌تر بوده و به مراقبت‌های پزشکی پیچیده حیات‌بخشی کمتری در محل حادثه دارد.

در پژوهش شماره ۳ همه تروماهایی که در مالمو به وقوع پیوسته به نحو توصیفی مورد مطالعه قرار گرفته، همچنین جزئیات رسیدگی‌های اورژانسی در بیمارستان مانند رادیوگرافی، عمل جراحی و رسیدگی‌ها در بخش مراقبت‌های ویژه مورد مطالعه قرار گرفت. این بررسی نشان داد که در مدت سه سال تعداد ۱۲۵ مورد ترومای شدید و ۳۰۳ مورد ترومای نسبتاً شدید در مالمو اتفاق افتاده است. ترافیک و زمین خوردن بیشترین سازوکار بروز چنین آسیب‌هایی را ایجاد نموده است. افراد ۶۵ ساله و بالاتر بیشتر در معرض زمین خوردن قرار داشته‌اند. در مدت سه ماه مرگ و میر ۱۰/۳٪ بود. جراحات شدید طبق درجه‌بندی NISS با سن بالا و انتقال خون زیاد، با افزایش مرگ‌ومیر پیوند داشت. سی‌وسه نفر از ۴۴ بیمار فوت شده که توسط پزشکی قانونی مورد کالبدشکافی قرار گرفتند که ۵۲٪ از آنان حداقل یک نوع مواد مخدر یا دارو در بدن خود داشتند. پس از انجام تجزیه و تحلیل‌ها در اداره پزشکی قانونی ما نیز توانستیم تأیید کنیم که معمول‌ترین ماده مخدر یا دارویی که در کالبدشکافی پیدا شده عبارت بود از الکل (اتانول ۱۵٪)، داروی ضد افسردگی (۱۵٪) و داروی آرامبخش (۱۲٪). نزد ۱۲٪ از آنان هم نوعی از مواد مخدر پیدا شد.

در پژوهش شماره ۴ بر روی بررسی اهمیت کالبدشکافی پزشکی قانونی در مطالعه ترومای شدید تمرکز شد. طبق قوانین سوئد می‌بایست موارد فوت در اثر تروما برای انجام کالبدشکافی پزشکی قانونی به پلیس گزارش شود.

نتیجه این بخش از پژوهش این بود که ۱۷۴ نفر از ترومای شدید آسیب‌دیده‌اند که ۵۳٪ آن‌ها مرده‌اند. تعداد ۱۲۶ نفر بیمار در بیمارستان مورد شناسایی قرار گرفته‌اند و ۴۸ نفر هم مستقیماً از محل حادثه به پزشکی قانونی حمل شده‌اند. از بین آن‌هایی که به بیمارستان رسانیده شدند ۴۴ نفر مردند و ۷۵٪ از آنان مورد معاینات پزشکی قانونی قرار گرفتند. در بین کسانی که در محل حادثه مرده‌اند و به بیمارستان برده نشده بودند نسبت حوادث کمتر و خودآزاری بیشتر بود. همچنین گلوله خورده‌ها در مقایسه با کسانی که از همان ابتدا به بیمارستان رسانده شده بودند، بیشتر بود.

عواملی که با فراوانی کمتری از کالبدشکافی در پزشکی قانونی در مطالعه گروه مورد مطالعه تداعی داشت عبارت بودند از: سن بالا، آسیب‌های شدید از درجه پایین‌تر همچنین زمین‌خوردن.

نتیجه این پایان‌نامه به‌طور خلاصه چنین است که ترومای شدید در شهر مالمو با درآمد پایین و نیاز به کمک‌های مالی برای گذران زندگی درآمیخته است اما نه با سطح تحصیلات.

به نظر نمی‌رسد که «ساعت طلایی» یا زمان پاسخ زیر ۸ دقیقه عامل تعیین‌کننده‌ای برای پیش‌بینی مرگ‌ومیر پس از تروما در شهر مالمو باشد.

برای ارزیابی بهتر اهمیت مدت زمان مراقبت‌های پزشکی پیش از بیمارستان در رابطه با بیماران مصدوم، پیشنهاد ما این است که در پژوهش‌های بعدی در باره دآوری پرسنل همراه آمبولانس در مورد شدت آسیب‌دیدگی در محل حادثه تحقیق شود. این پژوهش شاید بتواند نشان دهد که دآوری پرسنل همراه آمبولانس در باره شدت آسیب وارده می‌تواند معیار تشخیص بهتری از مدت زمان عملیات نجات بیمار برای پیش‌بینی نتیجه باشد. پیش از هر چیز باید ارزیابی رابطه بین مدت زمان ماندن در محل حادثه و دآوری پرسنل همراه آمبولانس مورد توجه باشد.

ما همچنین ثابت کردیم که هر زمان که خشونت و تروما در تمامیت آن در بین مردم مورد پژوهش قرار می‌گیرد، مهم است که داده‌ها از بیمارستان‌ها و پزشکی قانونی هردو گردآوری شود. پژوهش‌های ما نه تنها چنین تجزیه و تحلیلی را همراه داشت که بیش از نیمی از کسانی که از

ترومای شدید آسیب‌دیده اند در اثر صدمات وارده مرده اند بلکه بسیاری از آنان نیز اثری از ماده مخدر/ دارو در بدن خود داشته اند که نشان‌دهنده دلزدگی از زندگی و یا کاهش عملکرد پیش از زمان بروز صدمات است. نسبت بالای یافته‌های سم‌شناسی از موارد کالبد شکافی پزشکی قانونی نشان می‌دهد که غربالگری سم‌شناسی در همه موارد ترومای شدید می‌بایست در همه پذیرش‌های اورژانس متداول شود؛ بخشی به خاطر دادن خدمات پزشکی به بیمار مصدوم و بخشی دیگر برای پیشگیری از ترومای افراد جامعه در آینده.

علاوه بر این بر طبق قوانین سوئد ۲۵٪ از کل ترومای منجر به فوت در بیمارستان‌ها می‌بایست در پزشکی قانونی کالبدشکافی شوند.

این بسیار مهم است که پرسنل درمانی و سیاست‌مداران عوامل خطر را در جامعه شناسایی کنند و تلاش نمایند اقداماتی را انجام دهند تا این‌گونه افراد جانشان را پیش‌هنگام از دست ندهند. اکنون همکاری بین گروه پژوهشی ما و کلینیک اورژانس در بیمارستان‌های مالمو برای انجام آزمایش وجود مواد مخدر و دارو در خون در موارد ترومای شدید و شناسایی افرادی که در معرض خطر بازگشت دوباره تروما هستند، در جریان است.

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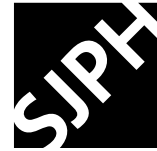
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Study I



ORIGINAL ARTICLE

Socio-economic status and major trauma in a Scandinavian urban city: A population-based case-control study

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Abstract

Aims: Epidemiological studies of patients with major trauma, including both hospitalized and immediately deceased whom are undergoing medico-legal autopsy, are very rare. We studied the incidence and mortality of major trauma in all 10 districts in the Scandinavian city of Malmö, Sweden, and the association between socio-economic status and major trauma. **Methods:** Major trauma was defined as a New Injury Severity Score > 15, or a lethal outcome due to trauma. Cases with a registration address in Malmö between 1 January 2011 and 31 December 2013 were identified from the red trauma alarm list in the hospital and the autopsy register in the Forensic Department. Statistics Sweden matched each case with four randomly selected age-, gender- and district-matched controls. Social assistance within the household, level of education, income and capital income were compared. **Results:** We identified 117 cases (80 men and 37 women) with a median age of 48.0 years (IQR 28.5–65.0). The incidence of major trauma in Malmö was 12.7 (95% CI 10.4–15.0) per 100,000 person-years; and 69 died due to major trauma, with 8.4 (95% CI 6.4–10.4) per 1000 deaths. Lower income ($p = 0.024$), no income (OR 1.6; 95% CI 1.0–2.4; $p = 0.037$) and social assistance (OR 2.3; 95% CI 1.3–4.1; $p = 0.003$) were associated with major trauma. The level of education was not found to be related to major trauma ($p = 0.47$). **Conclusions: Low income and social assistance within the household were associated with major trauma in the city of Malmö, but not the level of education; in this age-, gender- and district-matched case-control study of major trauma.**

Key Words: Death, epidemiology, low income, social assistance, socioeconomic status, trauma, Sweden, unemployment

Introduction

Major trauma is the largest single factor for death and severe disability in the younger population whom are < 40 years old, worldwide [1]. The population of Malmö, Sweden, has been studied extensively in epidemiological surveys involving fatal diseases [2,3,4], cardiovascular diseases [5] and cancer [6]. Malmö, a population with a wide socio-economic spectrum, is a city with unique opportunities to study the relationship between trauma and socio-economic factors.

It is rare that epidemiological surveys of patients with major trauma include both hospitalized and

immediately deceased individuals undergoing forensic autopsy [7]. We applied data from both registers to use the New Injury Severity Score (NISS) [8], which is recommended by the Swedish Trauma Registry (SweTrau) [9], to study the socio-epidemiological aspects of major trauma.

The main aim of the present study was to estimate the gender-specific incidence and mortality regarding major trauma in the 10 districts in the city of Malmö, and the association between socio-economic status (SES) and major trauma in a population-based case-control study.

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Materials and methods

Our study was approved by the Regional Ethical Review Board in Lund, Sweden (Dnr 2014/287).

Setting

Malmö City Hospital, part of the Skåne University Hospital, has a primary catchment population of 400,000 individuals. The emergency department in this hospital had an annual visit of 84,000 patients, of whom about 700 cases were triaged at the emergency department as trauma alarms, according to the Medical Emergency Triage and Treatment System (METTS). At the Department of Forensic Medicine in Lund, approximately 1000 medico-legal autopsies are performed yearly, at the request of the Police. Among the 590 medico-legal autopsies that were requested by the Malmö Police Department between 2011 and 2013, 245 death causes were non-natural.

City of Malmö

Malmö is the third largest city in Sweden. The average age of Malmö citizens is 38.7 years; and 22% of the Malmö population is under 20 years old, 63% is between 20–64 years, and 15% is older than 65 years of age. There are 136,500 households in this city: 70% were small households with one or two people in 2012. Malmö has over 177 nationalities represented.

About 31% (94,743 individuals) of the Malmö inhabitants are immigrants, and 11% (32,870) of the inhabitants are second-generation immigrants, with both parents born abroad. The four largest groups come from Iraq, the former Federal Republic Of Yugoslavia, Denmark and Poland.

In the 10 districts in Malmö, the local authorities have a Welfare Index (WI) compiled by 44 indicators. For each indicator, the districts are ranked on a scale from one (lowest) to 10 (highest) (Figure 1). This study's data was retrieved from different authority databases, such as: the Malmö Police Department, the Department of Public Health and Environment, the Swedish National Agency for Education, the Malmö Hospital and Swedish Dental Service organizations; as well as from questionnaires about students' living habits and the Malmö residents' psychological health, physical activity, and smoking and alcohol habits [10].

The economic status, level of education, overweight, health and physical activity, dental health, alcohol consumption, smoking, drug abuse, living conditions at home and well-being at school were

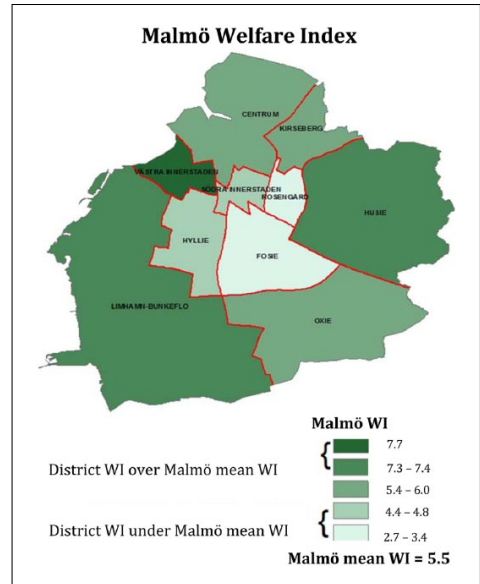


Figure 1. Malmö welfare index by district, showing whether it is over or under the mean.
WI: Welfare Index.

some of the indicators [11]. All the ranked values were then summed up for each district and divided by the number of indicators. This provided the information on Figure 1, which gives an indication of the district's social and welfare development.

The WI of the year 2012 showed that the district of Västra Innerstaden retained the highest value (7.9), followed by Limhamn-Bunkeflostrand and Husie (Figure 1). The districts Södra Innerstaden, Hyllie and Fösie had lower WI, and the district of Rosengård had the lowest WI (2.6).

Retrieval of patients

This is a population-based case-control study of both adults and children residing in the city of Malmö who were admitted to Malmö University Hospital between 1 January 2011 to 31 December 2013, and underwent the triage classification according to the METTS.

Patients were identified by a combined search of all the red trauma alarms registered in the databases at the Emergency and Anesthesiology departments. Besides these two registers, the patients in the forensic autopsy register were searched for and identified, using the codes for "non-natural death". Patients were

excluded from the study for the following reasons: erroneous personal identification data ($n = 3$), burns without any other traumatic injuries ($n = 22$), hangings ($n = 7$), drownings ($n = 4$) and asphyxia ($n = 2$).

The patient's survival 3 months after the trauma was checked in the Swedish Population Registry.

Trauma definition

Trauma patients were defined according to the Scandinavian Networking Group for Trauma and Emergency Management (SCANTEM) [12], excluding drownings, hangings, asphyxia and burns without other traumatic injuries.

Injury severity in each trauma patient was assessed retrospectively by the NISS. The Abbreviated Injury Scale (AIS) classification system is a consensus-derived scoring system where a specific number combination refers to an injury severity scale, with categories ranging from minor injury (Scale 1) to most critical injury (Scale 5), as well as un-survivable injury (Scale 6). NISS is calculated by summing the squares of the three highest AIS injuries, regardless of body region [13].

In our study, major trauma was defined as a NISS > 15 , or if a patient had died at the trauma scene and been directly sent for medico-legal autopsy. The inter-rater reliability of NISS scoring, in relation to major trauma, has been found to be satisfactory [7].

Data collection

The data needed for this study were retrieved from electronic patient/case record systems at the hospital, and/or at the Department of Forensic Medicine.

Statistics Sweden

The population count and mortality in different city districts in Malmö were retrieved from Statistics Sweden (SCB) [14,15]. All the cases with major trauma were age-, gender- and city district-matched with four randomly selected controls within the city of Malmö, by SCB. SES in terms of income, capital income, social assistance within the household and level of education were collected for the year preceding the trauma. Thus, if the trauma date was 30 May 2013, the information at 31 December 2012 was used. SCB retrieved the data from the following databases: Geography database 2010–2012, Income and Taxation Register (IoT) 2010–2012, Education Register 2010–2012, Total Population Register (TPR) 2010–2013 and Longitudinal Integration Database (LISA) for the health insurance and labor

market studies. Controls were randomly selected from TPR [15].

Socio-economic classification

The annual income level of individuals ≥ 18 years of age was defined according to an accepted classification score from Statistics Sweden: Low Income = 0–15,273 € (0–142,332 Swedish crowns (SEK)); Medium Income = 15,274–37,209 € (142,333–346,746 SEK); and High Income, $> 37,209$ € ($> 346,746$ SEK). Capital income was defined as income due to capital savings, common stock holdings, ownership of properties or shares of a business.

Social assistance within the household is statutory economic help to those families with limited economic resources. The applying families can receive support from social services for their upkeep and for other items that they need to have for a reasonable standard of living. This economic support consists of a standard sum for personal expenses for each household member, plus reasonable costs for other common needs. The standard sum should cover costs that are reasonably similar for all; for example: costs for food, clothing and hygiene. If there are several individuals in the same household, the economic assistance is adjusted with respect to the total number of individuals. In 2012, the standard sum for each adult was 313 € (2920 SEK) per month for singles and 566 € (5270 SEK) for two persons living together [16]. The sum is what the household needs to survive for a month; and the economic need is then compared with the household income, to see if it is above or below the limit for obtaining financial assistance. In 2012, social assistance was paid to 14,602 (11%) of the households in Malmö.

In 2012, 46% of the Malmö population between 25 and 64 years of age had an educational level higher than high school: 50% for women and 43% for men, respectively [10]. The overall percentage for the entire country of Sweden was 40%.

In our study, the level of education in individuals ≥ 25 years was defined as being low (elementary school or less), medium (high school) or high (any higher education after high school); corresponding to ≤ 9 years, 10–12 years and > 12 years of schooling, respectively. An age of 25 was considered a reasonable age for reaching a final educational level.

Statistical methods

Data management and statistical analysis were performed using SPSS for Windows, version 20.0 (SPSS, Chicago, IL, USA). We analyzed the differences in

Table I. Incidence of major trauma in Malmö Citizens 2011–13 in relation to gender in all ten districts.

District	Population at risk			All major traumas			Incidence (95% C.I.) /100 000 person years		
	M	F	M+F	M	F	M+F	M	F	M+F
Centrum	23101	24070	47171	5	4	9	7.2 (2.3 – 16.8)	5.5 (1.5 – 14.2)	6.4 (2.9 – 12.1)
Södra Innerstaden	17319	17352	34671	11	5	16	21.2 (10.6 – 37.9)	9.6 (3.1 – 22.4)	15.4 (7.9 – 22.9)
Västra Innerstaden	15071	18120	33191	7	5	12	15.5 (6.2 – 31.9)	9.2 (3.0 – 21.5)	12.1 (6.2 – 21.1)
Limhamn-Bunkeflo	21065	21581	42646	5	6	11	7.9 (2.6 – 18.5)	9.3 (3.4 – 20.2)	8.6 (4.3 – 15.4)
Hyllie	15564	17434	32998	16	8	24	34.3 (17.5 – 51.1)	15.3 (7.4 – 30.1)	24.2 (14.5 – 33.9)
Fosie	21764	22125	43889	15	3	18	23.0 (11.4 – 34.6)	4.5 (0.9 – 13.2)	13.7 (7.4 – 20.0)
Oxie	6243	6210	12453	7	2	9	37.4 (15.0 – 77.0)	10.7 (1.3 – 38.8)	24.1 (11.0 – 45.7)
Rosengård	11853	11710	23563	8	2	10	22.5 (9.7 – 44.3)	5.7 (0.7 – 20.6)	14.1 (6.8 – 26.0)
Husie	10285	10484	20769	2	2	4	6.5 (0.8 – 23.4)	6.4 (0.8 – 23.0)	6.4 (1.7 – 16.4)
Kirseberg	7736	7223	14959	4	0	4	17.2 (4.7 – 44.1)	0.0 (0.0 – 17.0)	8.9 (2.4 – 22.8)
All	150001	156309	306310	80	37	117	17.8 (13.9 – 21.7)	7.9 (5.4 – 12.4)	12.7 (10.4 – 15.0)

Major trauma defined as NISS > 15 or undergoing forensic autopsy after trauma. The Malmö population of 2012 was defined as the average population in the analysis.

All cases defined as the sum of cases retrieved from hospital records or forensic autopsies.

proportions using Kendall's tau-b test, the chi-squared or the Fisher's exact test; which were expressed in *p*-values and, when appropriate, in Odds Ratios (ORs) with 95% confidence intervals (CI). Continuous variables were expressed in medians and interquartile ranges (IQR), and group differences were evaluated with the Mann-Whitney U test. The incidence rate of the population at risk and the cause-specific mortality ratio, in relation to gender in all 10 districts during the 3-year study time were expressed as 95% CI per 100,000 person-years and per 1000 deaths, respectively. We used Spearman's correlation coefficient (*r*) to evaluate the correlations between the mechanism of injury and income, social assistance or level of education. We considered that *p* < 0.05 was significant. We converted the levels of income and the levels for economic assistance within a household from SEK to Euros by using the mean average exchange rate in 2012 (www.oanda.com; 100 SEK = 10.73 Euro).

Results

Patient characteristics of individuals with major trauma

We identified 117 individuals with major trauma, 80 men and 37 women, as residents in Malmö according to the city population register. Their median age was 48.0 years (IQR 28.5–65.0) and seven (6%) cases were children. Among all these cases with major trauma, 63 (54%) were caused by accidents, 30 (26%) were self-inflicted and 20 (17%) were caused by assault/homicide. In four cases (3%), the cause of the trauma was unclear. We found that 44 (34%) out of the 117 individuals with major trauma were involved in falls, 33 (28%) had road traffic injuries and 30 (26%) had been subjected to penetrating trauma (e.g. gun shot or sharp objects).

Incidence of major trauma

The incidence of major trauma in Malmö was 12.7 (95% CI 10.4 – 15.0) per 100,000 person-years (Table I). The incidence was higher for men than for women, 17.8 (95% CI 13.9–21.7) per 100,000 person-years and 7.9 (95% CI 5.4–12.4) per 100,000 person-years, respectively.

Mortality of major trauma

The cause-specific mortality ratios in relation to gender, in the 10 districts in Malmö, are shown in Table II. There were 69 individuals who died due to major trauma, 45 men and 24 women, which corresponded to an overall trauma-related mortality of 8.4 (95% CI 6.4–10.4) per 1000 deaths in Malmö citizens. The mortality rate was higher for men than for women. It was 12.0 (95% CI 8.5–15.5) per 1000 deaths and 5.4 (95% CI 3.2–7.6) per 1000 deaths, respectively.

Correlation between socio-economic status and major trauma

Receipt of social assistance within a household was significantly inversely correlated to fall accidents (*r* = – 0.193; *p* = 0.037), as seen in Table III. Fall accidents were correlated to age (*r* = 0.36; *p* < 0.001) and social assistance was correlated to a lower age (*r* = 0.185; *p* = 0.046). There was a significant correlation between the level of education and income (*r* = 0.192; *p* < 0.001).

Socio-economic status

Income for the major trauma victims was lower, compared to the control group (*p* = 0.024), as seen in Table IV: There were 64 (58.2%) out of 117 cases

Table II. Mortality from trauma in Malmö Citizens 2011 – 13: Cause-specific mortality ratios in relation to gender in all ten districts.

District	Deaths 2011 – 13			Deaths from trauma*			Cause-specific mortality (95 % C.I.) /1000 deaths		
	M	F	M+F	M	F	M+F	M	F	M+F
Centrum	423	536	959	4	1	5	9.5 (2.6 – 24.2)	1.9 (0.05 – 10.4)	5.2 (1.7 – 12.2)
Södra Innerstaden	376	449	825	6	2	8	16.0 (5.9 – 34.7)	4.5 (0.5 – 16.1)	9.7 (4.2 – 19.1)
Västra Innerstaden	444	670	1114	3	4	7	6.8 (1.4 – 19.7)	6.0 (1.6 – 15.3)	6.3 (2.5 – 12.9)
Limhamn-Bunkeflo	520	590	1110	1	6	7	1.9 (0.05 – 10.7)	10.2 (3.7 – 22.1)	6.3 (2.5 – 13.0)
Hyllie	636	717	1353	10	6	16	15.7 (7.5 – 28.9)	8.4 (3.1 – 18.2)	11.8 (6.0 – 17.6)
Fosie	549	588	1137	13	3	16	23.7 (12.6 – 40.5)	5.1 (1.1 – 14.9)	14.1 (7.2 – 21.0)
Oxie	141	154	295	3	1	4	21.3 (4.4 – 62.2)	6.5 (0.2 – 36.2)	13.6 (3.7 – 34.7)
Rosengård	186	223	409	1	0	1	5.4 (0.1 – 30.0)	0.0 (0.0 – 16.5)	2.4 (0.1 – 13.6)
Husie	280	246	526	2	1	3	7.1 (0.9 – 25.8)	4.1 (0.1 – 22.7)	5.7 (1.2 – 16.7)
Kirseberg	198	245	443	2	0	2	10.1 (1.2 – 36.5)	0.0 (0.0 – 15.1)	4.5 (0.5 – 16.3)
Total	3753	4418	8171	45	24	69	12.0 (8.5 – 15.5)	5.4 (3.2 – 7.6)	8.4 (6.4 – 10.4)

*including forensic autopsies.

Table III. Correlation between income, social assistance, educational level and mechanism of major trauma.

Variable	n (%)	Income		Social assistance		Education level	
		r	p	r	p	r	p
Cause of trauma							
Accident	63/114 (55.3)	0.014	0.890	-0.096	0.307	0.019	0.860
Self-inflicted	30/113 (26.5)	0.006	0.950	-0.133	0.161	0.051	0.635
Mechanisms of injury							
Penetrating injury	30 (25.6)	-0.023	0.814	0.118	0.204	-0.096	0.356
Gun shot	19 (16.2)	-0.053	0.582	0.085	0.364	-0.113	0.279
Knife/Sharp objects	10 (8.5)	0.066	0.490	0.088	0.348	0.053	0.615
Blunt injury	87 (74.4)	0.023	0.814	-0.118	0.204	0.096	0.356
Fall accident	44 (37.6)	-0.064	0.510	-0.193	0.037	0.028	0.790
Traffic accident	33 (28.2)	0.079	0.410	0.039	0.679	0.066	0.526

Table IV. Socio-economic status in patients with major trauma, in relation to age-, gender- and city district matched controls in Malmö City.

	Cases (n=117) (%)	Controls (n=468) (%)	P-value	OR (95% CI)
Income²				
Low	81/110 (73.6)	285/440 (64.8)		
Medium	23/110 (20.9)	93/440 (21.1)		
High	6/110 (5.5)	62/440 (14.1)	0.024	
No income²	64/110 (58.2)	207/440 (47.0)	0.037	1.6 (1.0 – 2.4)
Capital income²				
Deficit	45/110 (41)	188/440 (42.7)		
None	33/110 (30)	130/440 (29.5)		
Profit	32/110 (29)	122/440 (27.7)	0.72	
Social assistance within household	22/117 (18.8)	42/468 (9.0)	0.003	2.3 (1.3 – 4.1)
Education level¹				
Low	28/94 (29.8)	87/363 (24.0)		
Medium	38/94 (40.4)	165/363 (45.5)		
High	28/94 (29.8)	111/363 (30.5)	0.47	
Low vs medium/high	28/94 (29.8)	87/363 (24.0)	0.25	1.3 (0.8 – 2.2)

¹≥ 25 years.²≥ 18 years.

with major trauma whom had no income, compared to 47.0% for the controls (OR 1.6; 95% CI 1.0–2.4; $p = 0.037$). Only 5.5% of cases with major trauma

had high income. The proportion of cases who received social assistance within a household was 18.8% in those with major trauma, versus 9.0% in

the control group (OR 2.3; 95% CI 1.3–4.1; $p = 0.003$). There were no differences in capital income nor level of education, between the two groups.

Discussion

The present case-control study showed that a lower income and the need of social assistance within the household was associated with an increased risk of major trauma in Malmö, a Scandinavian city in a high-income country.

Although the importance of SES as a risk factor for trauma injuries is well-documented [17,18], the magnitude and the type of trauma varies largely by country and income level. For example, in a high-income country like Australia, the majority of major trauma (88.6%) patients sustained their injuries from unintentional events (accidents), mostly traffic and falling accidents, and this rate is similar in USA [19]. In a country such as South Africa, with well-known problems due to segregation and low socio-economic infrastructure, interpersonal violence was the largest leading cause of death, followed by road traffic injuries; and trauma mortality rates were 7 times the global rate [20].

The present study showed that it is important to include social assistance to households as a variable in the epidemiological studies on SES. Social assistance reflects low economic resources, which may increase these individuals' vulnerability to mental illness, low self-confidence and depression [21]; therefore, exposure to trauma. One should be aware that the variable of social assistance is subject to a risk for bias, in that an unknown proportion of households may have received social assistance erroneously, due to dishonest applications; whereas some households that would have been granted social assistance may never have applied.

The higher rate of incidence of and mortality due to trauma, in men versus women, was shown in this paper and reflects the fact that men are more exposed to trauma [22]. Globally, almost twice the number of males versus females are killed by injuries and violence; and about three-quarters of all deaths from road traffic injuries occur in men [23]. This could be explained by high-risk behavior in men and the higher frequency of male drivers.

Reports from the World Health Organization (WHO) have also indicated that there is a strong correlation between health and the level of education [24]. Poor health affects the person's educational level and chances in the labor market; and therefore, also their economic, physical and psychosocial well-being. Reports have indicated that those with low SES, such as those with a lower educational level, were less healthy and more often suffered from chronic pain, depression and anxiousness, as compared to those from better economic situations [25]. The absence of

an association between the educational level and major trauma in the present study may be attributed to the strictly district-matched control groups. A recent publication on major trauma patients in Stockholm, another city in Sweden, reported that a low level of education was an independent risk factor for trauma, after comparison with a municipality-matched control group [26]. This discrepancy between the two studies reflects the importance of the selection of the control group. The person's place of residency appears to reflect the socio-economic standards, such as income and level of education, to a large extent [11,23,27].

In contrast to previous reports [26,28], we observed that there was no association between education and major trauma. We do recognize that our study suffers from low statistical power, when investigating education as an exposure for major trauma; but we also used a different approach compared to the previous studies [26,28], because our matching also included residential area. We speculate that our results have indicated that education has no separate effect, above and beyond that of the residential area, on major trauma.

SES largely differs between the city districts in Malmö, probably much depending on a similar group togetherness and local culture within the same district, which has a strong unifying force between citizens with the same social background, influencing their income and also health conditions. Lower SES in a district indicates that socio-economic factors such as poverty, overcrowded housing, less social fellowship and higher mental illness have a great impact on the educational level [25,29]. Statistics from the Swedish national agency for education showed < 30% of the children from the district of Rosengård (with the lowest WI in Malmö) managed to pass the entry requirements for high school, during the past 5 years, as compared to 93% of the children in the district of Limhamn-Bunkeflo (with one of the highest WI in Malmö) [27]. Hence, we hypothesized that if we did not compare the present study cases with controls within the same district, but instead with the entire municipality of Malmö, the educational level would probably have also been shown to be a significant risk factor for major trauma.

The limitations of the present study may be attributed to the relatively few patients with major trauma from their respective districts; and hence, the risk of a Type II statistical error. On the other hand, these cases were well scrutinized, with retrieval of data from both the hospital and medico-legal records, and with properly matched controls.

The WHO Regional Committee for Europe's resolution emphasizes that the government's social and economic policies strongly influence families' susceptibility to trauma, by affecting their social and physical environments in the society [30]. Prevention of trauma requires awareness of the risks that are connected with

the susceptibility of injuries, including the knowledge of the common denominator in the districts with lower SES and the higher likelihood of trauma. It is important to identify the hazards at work, home and in commuting environments; as well as to establish community-based programs with the intention to educate and change peoples' lifestyles and behaviors [30]. Individuals with health problems and mental illness in the areas with lower SES are at increased risk of major trauma [26], and their susceptibility to injury may also be due to a lack of economic resources for preventive safety measures [30].

Conclusions

This population-based study, matching cases with age-, gender-, and city district-matched controls, showed that low income and social assistance within the individuals' households were associated with major trauma in the city of Malmö; whereas their level of education was not.

Conflict of interest

The authors declare that there are no conflicts of interest.

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Study II

Analysis of pre-hospital rescue times on mortality in trauma patients in a Scandinavian urban setting

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Abstract

Objective: To analyze if pre-hospital rescue times were associated with mortality in a trauma cohort arriving by ambulance to hospital in a Scandinavian urban setting.

Methods: Between 2011 and 2013, individuals and pre-hospital rescue times were identified in Emergency Medical Dispatcher Centre, hospital, and forensic records in red alarm trauma. Major trauma was defined as a New Injury Severity Score (NISS) > 15.

Results: Overall, 89% of 378 trauma patients received hospital care within 60 min; 51% had a response time of ≤8 min, and 95% had response time within ≤20 min. The on-scene time ($p < 0.05$) and total pre-hospital time ($p < 0.05$) were longer for patients ≥65 years, in comparison with patients <65 years. The patients with penetrating trauma had shorter on-scene time ($p < 0.01$), total pre-hospital time ($p < 0.01$), and shorter transport distance from trauma scene to hospital ($p = 0.004$), compared to those with blunt trauma. Patients with NISS > 15 were found to have the same pre-hospital rescue times as those with NISS ≤ 15. There was a trend that the occurrence of gunshots was associated with increased mortality ($p = 0.074$). When entering age, NISS, penetrating versus blunt injury, response time, and on-scene time in a multivariate regression analysis, age ($p < 0.001$), NISS ($p < 0.001$), and penetrating injury ($p = 0.009$) remained as independent factors associated with mortality and a trend for shorter on-scene time ($p = 0.093$).

Conclusions: Pre-hospital rescue times had less impact on mortality than injury severity, age, and penetrating trauma. Even though penetrating traumas were associated with shorter on-scene time and shorter transport distance to hospital, mortality was increased in this Scandinavian urban setting.

Keywords

Trauma, New Injury Severity Score, mortality, response time, on-scene time, total pre-hospital time

Introduction

Trauma is the largest single cause of mortality and severe morbidity in the younger population (<40 years) and the third leading cause of lost disability-adjusted life-years worldwide.¹ During the last decades, efforts to improve the competence of the emergency medical services (EMS) have been made including improved technical equipment and better delivery of Advanced Life Support (ALS). Previous studies have investigated whether it is better to immediately transport the injured patient to the hospital ('scoop and run/load and go') or to treat and stabilize the patient on the trauma scene and then transport the patient ('stay and play')² with conflicting results.^{3,4}

There is a general belief that trauma outcome after injury is improved if the total pre-hospital time is as

short as possible. A pre-hospital time of less than 60 min after trauma, the 'golden hour', has for a long time been an accepted goal to improve trauma care in many trauma centers. The response time, i.e., time between a phone call to the Emergency Medical

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Dispatcher Centre services and the arrival of ambulance to scene, has also been considered of importance. A response time of less than 8 min has been shown to be associated with a better outcome.^{3,4} Studies on the influence of pre-hospital rescue times in relation to injury severity on mortality has been extensively investigated in other parts of the world but scarcely investigated in Scandinavian urban cities.

The aim of this study was to analyze if pre-hospital rescue times, response times, on-scene times, and total pre-hospital times, were associated with mortality in a trauma cohort arriving by ambulance to hospital in a Scandinavian urban city.

Materials and methods

The study was approved by the Regional Ethical Review Board in Lund, Sweden (Dnr 2014/287).

Setting

Malmö City has a population of 400,000 inhabitants; about 84,000 patients visit the emergency department (ED) annually and 700 of those are trauma alarms. Malmö university hospital is a level III trauma center. Patients that die due to trauma are sent to the Department of Forensic Medicine in Lund, for a medico-legal autopsy by request from the Police authority.

Retrieval of patients

This is a retrospective cohort study of both adults and children admitted by ambulance to the ED at Malmö University Hospital between 1 January 2011 and 31 December 2013. On arrival to the hospital, patients underwent triage classification according to the Medical Emergency Triage and Treatment System (METTS) and those classified as either priority one (red alarm) or Children trauma alarm were included in the study. The data needed for the study were retrieved from electronic patient record systems at the hospital, the EMS, Emergency Medical Dispatcher Centre, the hospital archive (Region archive services), and from the Department of Forensic medicine.

Patients were excluded for the following reasons: Arrival to the hospital was not by ambulance ($n=31$), transportation from other hospital ($n=5$), unrecognized/missing pre-hospital case number in the ambulance report ($n=14$), or declared dead at the trauma scene and not transported to hospital ($n=48$).

The patient's survival three months after the trauma was checked in the Swedish Population Registry. Shock at admission was defined as systolic blood pressure ≤ 90 mm Hg.

Trauma definition

Trauma patients were defined according to the Scandinavian Networking Group for Trauma and Emergency Management,⁵ excluding drowning's, hangings, asphyxia, and burns without other traumatic injuries. Mortality data after three months following the trauma event was collected from the Swedish Population Registry. A resident doctor in emergency medicine scored the hospital patients ($n=397$) and the forensic pathologists in the study group scored the cases subjected to a medico-legal autopsy ($n=31$). The trauma injury severity was assessed retrospectively using the Abbreviated Injury Scale (AIS) scoring system which is an anatomically based scoring system where a specific number refers to an injury severity scale, ranging from minor injury (scale 1) to most critical injury (scale 5) and un-survivable injury (scale 6). In this study, $AIS \geq 3$ was used as an indicator of serious injury. The New Injury Severity Score (NISS) was calculated by summing the squares of the three highest AIS injuries, regardless of body region.⁶ A $NISS > 15$ and $NISS \leq 15$ is defined as major and minor trauma, respectively. The inter-rater reliability of the NISS scoring has been evaluated in a previous report.⁷

Emergency medical services

In Sweden, the emergency phone number 1-1-2 connects to an alarm operator at emergency medical dispatch centers across Sweden. Their evaluation, decision-making process, and priority are based on a nationwide criteria-based priority dispatch tool called Swedish Emergency Medical Index. Annually, 114,000 medical emergency calls are received, corresponding to an emergency call incidence of 88 calls per 1000 inhabitants.

Pre-hospital ambulance organization

Skåne county, the southern part of Sweden, consists of 33 municipalities and has approximately 1.3 million inhabitants, which is 13% of the Swedish population. In 2012, 144,939 ambulance missions were carried out, of which 54,863 were Priority one missions (traumatic and non-traumatic). For all red (potentially life threatening cases) Priority one ambulance assignments, there is an accessibility goal of reaching 90% of the patients within 20 min and 99% of red priority within 35 min.⁸

Since 2010, the fire services in the county has received 16.5 h of training in basic life support (non-invasive methods) including cardiopulmonary resuscitation. The fire services also respond to trauma alerts and the site of the trauma might need to be secured before being accessed by the ambulance service.

Pre-hospital training skills in Malmö

Since 2005, the emergency ambulance team consists of both paramedics and ambulance specialist nurses who have undergone a three year education at the university and one year of specialist nurse education.

In current requirements, an ambulance team consists of at least one specialist nurse and one registered nurse without further specialist education or a paramedic.

A specialist nurse has the delegation to deliver ALS by invasive methods such as intubation of the airways under certain criteria, use a manual defibrillator, and administer certain drugs. Ambulance paramedics are usually assistant nurses with a further training of only about 20-weeks training of ambulance care.⁸

Trauma alarm in the hospital

The trauma alarms are classified by the nurses in the ED into red or non-red (orange) alarms, using METTS. In this triage system, the vital parameters and the type of injury are combined to provide four priority levels.⁹ Briefly, affected vital parameters, such as oxygen saturation, breathing frequency, pulse, systolic blood pressure, reaction level scale, and the type of trauma such as penetrating injury to the head, neck or trunk, more than one fracture of the long bones, unstable pelvis or chest, amputation of extremities, spine injury with neurologic loss, are criteria for red alarm. After April 2013, all the children (<15 years) traumas are alerted separately and triaged as red alarm ‘Children trauma alarm’ without any other priority levels.

Definition of pre-hospital time intervals

Response time was defined as the time of the initial call for medical assistance to the time when the ambulance arrived to the trauma scene. On-scene time was the time spent at the scene for treatment and loading of the patient, and transport time was

the time from departure from trauma scene to arrival at the hospital for definitive care. Total pre-hospital time was defined as the total time spent between the emergency call and the arrival at the hospital (Figure 1). All pre-hospital time intervals were measured continuously in minutes and also categorized as non-continuous variables: response time (≤ 8 min),¹⁰ on-scene time (<10 min, 10–19 min and ≥ 20 min),⁴ and total pre-hospital time (≤ 60 min).¹¹ The transport distance between the trauma scene and Malmö hospital was expressed in kilometers using the shortest roadway distance shown by Google Maps (www.google.se/maps).

Statistical methods

Data management and statistical analysis were performed using SPSS for Windows, version 20.0 (SPSS Inc, Chicago, IL). Differences in proportions were analyzed using Kendall’s tau-b test, chi-square, or Fisher’s exact test, and expressed in p values and, when appropriate, in Odds ratios with 95% confidence intervals. Continuous variables were expressed in medians and interquartile ranges (IQR), and group differences were evaluated with the Mann–Whitney U test; p value <0.05 was considered significant. Independent covariates associated with mortality were analyzed in a multi-variable regression model.

Results

Comparison of pre-hospital rescue times with trauma characteristics

In total, 378 patients were included in this study. The overall median response time was 8 min (IQR 6–12), the overall median on-scene time was 17 min (IQR 11–23), and the overall median total pre-hospital time was 35 min (IQR 27–46) (Table 1). The on-scene time (p < 0.05) and total pre-hospital time (p < 0.05) were

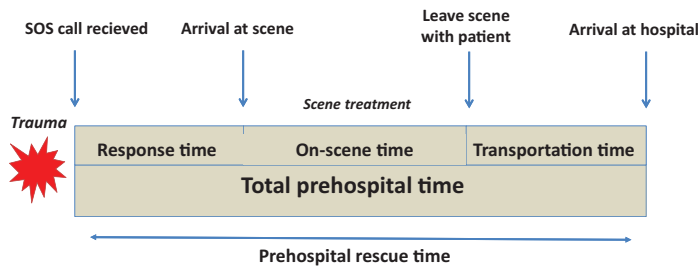


Figure 1. Pre-hospital time intervals.

Table 1. Comparison of pre-hospital rescue times with trauma characteristics.

	N (%) of all eligible patients	Median (IQR) Response time (min)	Median (IQR) On-scene time (min)	Median (IQR) Total pre-hospital time (min)
All patients	378	8 (6–12) (n = 352)	17 (11–23) (n = 340)	35 (27–46) (n = 357)
Children (<18 years)	80 (21)	9 (6–11) (n = 75)	15 (10–23) (n = 72)	35 (26–46) (n = 76)
Elderly (≥65 years)	45 (12)	8 (5–12) (n = 43)	20 (15–26) (n = 41)**	41 (29–52) (n = 43)**
Men	258 (68)	6 (8–12) (n = 237)	16 (11–22) (n = 227)	34 (27–45) (n = 241)
Women	120 (32)	9 (6–12) (n = 115)	17 (12–24) (n = 113)	36.5 (28–47) (n = 116)
Cause of trauma				
Accident	287 (76)	9 (6–13) (n = 263)	17 (12–23) (n = 253)	37 (27–48) (n = 267)***
Self-inflicted	47 (12)	7 (5–10) (n = 44)	19 (15–25) (n = 43)**	34 (27–41) (n = 44)
Assault/Homicide	49 (13)	8 (6–10) (n = 48)	13 (9–17) (n = 47)***	27 (24–34) (n = 49)***
Mechanisms of injury				
Penetrating injury	70 (19)	8 (5–11) (n = 69)	14 (9–19) (n = 68)***	28 (24–37) (n = 70)***
Gun shot	21 (6)	8 (5–11) (n = 20)	12 (9–19) (n = 19)**	27 (22–39) (n = 21)**
Knife/sharp objects	43 (11)	8 (5–11) (n = 43)	15 (10–19) (n = 43)**	29 (24–36) (n = 43)***
Blunt injury	308 (81)	9 (6–12) (n = 283)	17.5 (12–23) (n = 272)***	36 (27–47) (n = 287)***
Fall accident	117 (31)	9 (6–12) (n = 112)	20 (13–25) (n = 106)***	37 (29–48) (n = 114)**
Traffic accident	146 (39)	8 (6–12) (n = 133)	17 (12–21) (n = 129)	35 (27–51) (n = 135)
Battery/interpersonal violence	9 (2)	9 (8–11) (n = 9)	10 (9–16) (n = 9)**	29 (27–35) (n = 9)

IQR: interquartile ranges.

** $p < 0.05$, *** $p < 0.01$

longer for patients ≥ 65 years, in comparison with patients < 65 years.

There was a shorter on-scene time ($p < 0.01$) and total pre-hospital time ($p < 0.01$) in assaults/homicide patients compared to both accidents and self-inflicted trauma. The patients who had self-inflicted injuries had a prolonged ($p < 0.05$) on-scene time of 19 min (IQR 15–25) compared with those with non-self-inflicted injuries.

The patients with penetrating trauma had shorter on-scene time ($p < 0.01$) and total pre-hospital time ($p < 0.01$), compared to those with blunt trauma. The median NISS score in patients with penetrating injuries was 6 (IQR 3–17), compared to 8 (IQR 1–18) in blunt injuries, ($p = 0.89$). Patients with penetrating trauma were in shock at admission to hospital in 17% (11/66), compared to 10.8% of cases (31/286) in blunt trauma injuries ($p = 0.27$).

The on-scene time was shorter for gunshots ($p < 0.05$) and for injuries due to knife or penetrating objects ($p < 0.05$), compared to those without these injury mechanisms.

Individuals with fall injuries, compared to non-fall injuries, had a significantly longer on-scene ($p < 0.01$) and total pre-hospital time ($p < 0.05$). The median transport distance from trauma scene to hospital was significantly shorter in penetrating injuries compared to blunt injuries, 3.4 km (IQR 2.4–4.7) and 4.4 km (IQR 2.9–10), respectively ($p = 0.004$).

Comparison of pre-hospital rescue times with severity of injury

Patients assessed as major trauma (NISS > 15) in hospital were found to have the same pre-hospital rescue times as those with minor trauma (NISS ≤ 15) (Table 2). Patients with any serious organ injuries (AIS ≥ 3 ; $n = 146$) in either the head-neck, thorax, abdomen, and/or pelvis-extremities regions were found to have the same pre-hospital rescue times as those with AIS < 3 in all body regions.

Pre-hospital time intervals and injury severity in relation to mortality

Overall, 89% of the patient population received hospital care within 60 min; 51% had a response time of ≤ 8 min, and 95% had response time within ≤ 20 min (Table 3). The overall mortality rate within three months was 11% in this trauma population with 44% of patients aged 65 years and beyond dying due to the trauma, compared to 7% of those younger than 65 years ($p < 0.001$). Both a NISS > 15 ($p < 0.001$) and NISS ≥ 25 ($p < 0.001$) were associated with increased mortality. The mortality was higher ($p < 0.001$) in trauma patients with shock on admission to hospital versus non-shock.

Median age among survivors and non-survivors was 29 years (IQR 18–48) and 63 years (IQR 44–83),

Table 2. Comparison of pre-hospital rescue times with severity of injury.

	Median (IQR) Response time (min)	Median (IQR) On-scene time (min)	Median (IQR) Total pre-hospital time (min)
All patients (n = 378)	8 (6–12) (n = 352)	17 (11–23) (n = 340)	35 (27–46) (n = 357)
All patients AIS ≥ 3 (n = 146)	8.5 (6–12.3) (n = 138)	17 (10–24.5) (n = 132)	35 (26–52) (n = 140)
NISS ≤ 15 (n = 260)	8 (6–11) (n = 241)	16 (12–22) (n = 234)	35 (27–44) (n = 244)
NISS > 15 (n = 118)	9 (6–12) (n = 111)	17.5 (10–25) (n = 106)	35 (26–52) (n = 113)
NISS ≥ 25 (n = 73)	8 (5.8–12) (n = 66)	18 (11–25) (n = 63)	36 (26–53.5) (n = 69)

NISS: New Injury Severity Score; IQR: interquartile ranges.

Table 3. Pre-hospital priority management, time intervals and severity of trauma in relation to mortality.

Variable	N (%) of all eligible patients	Mortality within three months (%)	Univariate analysis	
			OR (95% CI)	p value
Patients	378	43/378 (11)		
SOS priority to the ambulances				
Prio 1 (Red)	319 (84)	38/319 (12)	1.5 (0.6–3.9)	0.45
Prio 2 (Orange)	16 (4)	3/16 (19)	1.9 (0.5–6.8)	0.35
Unknown	43 (11)	2/43 (5)		
Pre-hospital times				
Response time ≤ 8 min	180/352 (51)	25/180 (14; n = 40)	1.7 (0.9–3.3)	0.13
Response time ≤ 20 min	336/352 (95)	37/336 (11; n = 40)	0.5 (0.15–2.0)	0.35
On-scene time < 10 min	45/340 (13)	8/45 (18; n = 39)	1.8 (0.8–4.3)	0.16
On-scene time 10–19 min	164/340 (48)	17/164 (10; n = 39)	0.8 (0.4–1.6)	0.54
On-scene time ≥ 20 min	131/340 (39)	14/131 (11; n = 39)	0.9 (0.4–1.8)	0.72
Total pre-hospital time ≤ 60 min	320/358 (89)	36/320 (11; n = 40)	1.1 (0.4–3.2)	0.89
Risk factors				
Elderly (≥ 65 years)	45 (12)	20/45 (44)	10.8 (5.2–22.3)	<0.001
Shock at admission	42/352 (12)	17/42 (40; n = 37)	9.9 (4.6–21.2)	<0.001
NISS > 15	118 (31)	39/118 (33)	31.6 (11.0–91.1)	<0.001
NISS ≥ 25	73 (19)	38/73 (52)	65.1 (24.1–176.4)	<0.001
Penetrating vs. blunt trauma	70 (19)/308 (81)	11 (16)/32 (10)	1.6 (0.8–3.4)	0.21
Gunshots	21 (6)	5 (24)	2.6 (0.9–7.6)	0.074

NISS: New Injury Severity Score.

respectively ($p < 0.001$). The median NISS score among survivors and non-survivors was 6 (IQR 1–14) and 38 (IQR 27–59), respectively ($p < 0.001$). The median response time among survivors and non-survivors was 9 min (IQR 6–12) and 8 min (IQR 5–11), respectively ($p = 0.33$). Median on-scene time among survivors and non-survivors was 17 min (IQR 12–23) and 15 min (IQR 10–22), respectively ($p = 0.32$). The median total pre-hospital time among survivors and non-survivors was 35 min (IQR 27–45) and 32 min (IQR 25–52), respectively ($p = 0.56$).

When entering age, NISS, penetrating versus blunt injury, response time, and on-scene time in a multivariate regression analysis, age ($p < 0.001$), NISS

($p < 0.001$), and penetrating injury ($p = 0.009$) remained as independent factors associated with mortality (Table 4).

When entering age, NISS, penetrating versus blunt injury, and total pre-hospital time in a multivariate regression analysis, age ($p < 0.001$), NISS ($p < 0.001$), and penetrating injury ($p = 0.005$) remained as independent factors associated with mortality.

Discussion

Apart from the expected findings that age and injury severity were risk factors for mortality,^{12,13} there was a trend that shorter on-scene time was associated with

Table 4. Analysis of variables associated with mortality.

Variable	Mortality within three months	
	Univariate analysis (p value)	Multivariate analysis (p value)
Age (years)	<0.001	<0.001
Pre-hospital times (min)		
Response time	0.33	0.50
On-scene time	0.32	0.093
Severity of injury		
NISS	<0.001	<0.001
Mechanisms of injury		
Penetrating vs. blunt	0.21	0.009

NISS: New Injury Severity Score.

higher mortality in patients sustaining traumatic injury and arriving to hospital by ambulance in a Scandinavian city. Penetrating traumas such as gunshots were related to shorter on-scene time, which partly may explain the relation between shorter on-scene time and higher mortality. We speculate that the EMS personnel, aware that a short on-scene time is crucial for the survival of a penetrating injury,¹⁴ choose to rather use a more strict adherence to the 'load and go' principle due to the short transport distances to hospital in Malmö city.

Transport distance and availability to a trauma center are important aspects of pre-hospital resuscitation. Reports have shown that transporting patients with major trauma to non-trauma hospitals, not capable of providing a high-quality trauma care, is associated with higher mortality.¹⁵ This indicates the need of different pre-hospital management strategies depending on the geographical distance to a trauma hospital, whether it is a trauma in an urban city or in rural areas.¹⁶

The 'Golden hour' (total pre-hospital time under 60 min)¹¹ or response time under 8 min did not seem to be a crucial factor predicting mortality in the Malmö trauma cohort, as it has been considered to be in the management of trauma patients in other parts of the world.^{10,11} To our knowledge, the only situation in which short response time has been demonstrated to largely decrease mortality has been in patients with non-traumatic cardiac arrest.¹⁰

We found a longer on-scene time and total pre-hospital time in elderly patients. One explanation could be that older people, to a larger extent, suffer from comorbidities and may have difficulties to mobilize, especially in trauma situations. We noticed that 55% of patients aged 65 years and beyond had major trauma injuries, compared to 27% among those less than 65 years old, probably contributing to prolonged on-scene times and

perhaps more advanced on-scene interventions. However, the present study could not demonstrate that injury severity was associated with prolonged pre-hospital time intervals.

The observed longer total pre-hospital time in the present study in blunt injuries such as in traffic accidents, compared to penetrating injuries, may be explained as most traffic accidents usually occurs on motorways or roads with higher car speed, often long distances to hospital. The shorter total pre-hospital time in penetrating injuries might be explained by a shorter on-scene time and the occurrence of injuries in more central district areas of the city near the hospital with short transport distances and less need of ALS at the trauma scene.

It is still a matter of debate whether the trauma patients should be stabilized at the trauma scene, and how much rescue efforts should be performed at scene, i.e., basic or ALS.

It should be acknowledged that trauma individuals are a very heterogeneous group and the mechanism of injury varies in different populations. Although the physiological aspects of the medical care should be the same, 'load and go' or the other principle, 'stay and play' may benefit the patient in different situations. Interestingly, Demetriades et al.¹⁷ showed that patients with severe trauma transported by private means had even better survival than those transported by the emergency services, indicating that the time factor may still be of importance in certain situations.

Although the American College of Surgeons has recommended short on-scene times and fast transport to the hospital,¹⁸ in 2003, the National Association of EMS Physicians avoided special time recommendations and suggested that response and transport times have regional dissimilarity, and therefore have to be locally determined.¹⁹

There are some limitations in this study. We only included patients who arrived to hospital by ambulance, and no data could be collected in those 48 patients declared dead at the trauma scene and not transported to the hospital or those transported to hospital by private transportation. There is a possibility that some patients who were dead at ambulance arrival at the scene had response times of more than 8 min and who, theoretically, would have been alive if the EMS had arrived sooner. However, these patients had probably to a larger extent sustained a major trauma with high NISS scores with low likelihood of survival. We also faced difficulties in collecting pre-hospital time interval data, but despite some incomplete documentation, we were still able to register about 90% of all needed data.

To further evaluate pre-hospital trauma care, we suggest a prospective study, where the EMS trauma

scoring¹³ at the trauma scene is compared to NISS scoring at hospital, to predict mortality. It might be that EMS trauma scoring is a better pre-hospital prognostic tool than pre-hospital rescue times and may dictate a better life-saving management on the trauma scene. In particular, the association between on-scene time and EMS trauma scoring should be of interest to evaluate.

Conclusions

Pre-hospital rescue times had less impact on mortality than injury severity, age, and penetrating trauma. Even though penetrating traumas were associated with shorter on-scene time and shorter transport distance to hospital, mortality was increased in this Scandinavian urban setting.

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Study III



ORIGINAL ARTICLE

Outcome after red trauma alarm at an urban Swedish hospital: Implications for prevention

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Abstract

Aims: We applied the new injury severity scoring system and studied mechanisms of injury and risk factors for mortality, in order to find potential preventive measures, in the present Scandinavian trauma cohort triaged through red trauma alarm according to the Medical Emergency Triage and Treatment System. **Methods:** Individuals were identified in hospital and forensic records. New injury severity scoring system >15 was defined as major trauma. Inter-rater reliability of new injury severity scoring system was expressed as intra-class correlation coefficient with 95% confidence intervals. **Results:** There were 125 major and 303 minor traumas. The intra-class correlation coefficient was 0.83 (95% confidence intervals 0.58–0.94) for major trauma and intra-class correlation coefficient was 0.96 (95% confidence intervals 0.89–0.98) for minor trauma. Traffic (37%) and fall (31%) accidents were the leading mechanisms of injury. Elderly (aged ≥65 years) were at an increased risk of fall accidents ($p<0.001$). The overall 3 month mortality rate was 10.3% (2% for new injury severity scoring system 16–24, 39% for new injury severity scoring system 25–40 and 68% for new injury severity scoring system >40). A higher new injury severity scoring system score ($p<0.001$), higher age ($p<0.001$), shock at admission ($p<0.001$), intensive care unit stay ($p<0.004$) and administration of massive red blood cell transfusion ($p<0.048$) were associated with mortality. Thirty-three patients underwent forensic autopsy and were tested positive for one or multiple drugs in 52% and 33%, respectively. **Conclusions:** The high prevalence of detected drugs among those undergoing forensic toxicological examination suggests that toxicology screening should be integrated into all red trauma alarm admissions, which may have implications on prevention of future trauma morbidity and mortality.

Key Words: Trauma, new injury severity score, outcome, forensic autopsy, forensic toxicology, prevention

Introduction

Major trauma is the largest single factor of death and severe disability in people under 40 years and the third leading cause of lost disability-adjusted life years worldwide [1]. Prevention of trauma is top priority, but prior to any preventive work that can be considered worthwhile, surveys are needed. A survey of trauma in Malmö, the third largest city in Sweden, has not yet been performed. Malmö has a centrally located hospital that receives all major traumas and the close collaboration with the Department of Forensic Medicine

in Lund is of great importance to be able to retrieve as complete data as possible. During a forensic autopsy, the forensic pathologist documents all external and internal injuries and signs of disease. Histological examination of selected organs are performed in the majority of cases based on the characteristics of the case, the forensic pathologist determines if body fluids are to be sampled for toxicological analyses and select analyses. Based on the findings during the autopsy and the results of the additional investigations, the forensic

pathologist determines the cause of death and the causality of the injuries and states the manner of death. The regular screening method for drugs at forensic autopsy uses blood from the femoral vein and covers over 220 substances including a number of pharmaceuticals, illicit drugs and alcohol.

Injury severity classification is considered mandatory in trauma outcome research and quality assessment. Reporting standards of trauma makes data on injury severity in relation to outcome understandable and generalizable to other settings. Compared to physiological scoring systems, anatomic scoring systems seem to better predict outcome of trauma patients [2]. The new injury severity score (NISS) [3] is one such classification system, which includes anatomical injury scaling, which has been recommended [4] and has been adopted by the Swedish Trauma Registry (Swetrau). NISS seems to perform superior in mortality prediction of blunt injuries [5].

The main aim of the present study was to apply the NISS score in this trauma cohort and to study mechanisms of injury and risk factors for mortality in order to find potential preventive measures in patients sustaining trauma and being triaged through red trauma alarm.

Materials and methods

The study was approved by the Regional Ethical Review Board in Lund, Sweden (Dnr 2014/287).

Setting

The emergency department at Malmö University Hospital has a primary catchment population of 400,000 inhabitants for major traumas. The emergency department has a yearly visit rate of 84,000 patients, of whom about 700 are trauma alarms. Individuals who die at the trauma scene, during transportation or at hospital are transferred to the Department of Forensic Medicine in Lund, for a forensic autopsy requested by the Police authority. Annually, 1000 forensic autopsies including toxicological analysis are performed at this forensic department. In all, 244 forensic autopsies due to suicide ($n=89$), accidents ($n=89$), homicide ($n=17$) and unclear unnatural cause of death ($n=49$) were requested by the Police authorities from Malmö between 2011 and 2013.

Trauma alarm

Triage according to Medical Emergency Triage and Treatment System (METTS) Adult has five sorting levels, where the vital parameters and contact cause are combined to provide four priority levels [6]. All

trauma alarms were classified into red and non-red alarms. Briefly, mechanisms of injury such as penetrating injury in the head, neck or trunk, at least two fractures of the long bones, unstable pelvis, amputation above hand or foot, trauma with smoke or burn injury, trauma with drowning or cooling accident, flail chest, back injury with neurological injury, combined with affected vital parameters such as oxygen saturation below 90%, pulse above 130 beats/min, reaction level scale above 3, breathing frequency above 30 or below 8 and systolic blood pressure below 90 mm Hg, are criteria for red alarm. All children traumas were also classified as a red alarm according to the METTS classification until April 2013. After this date all the alarms in children (<15 years) were alerted as 'children trauma alarm', with no other priority level at arrival. In red trauma alarm for adults, the following staff were alerted: emergency nurses; secretary; resident in general surgery; specialist in general surgery; specialist in anaesthesiology; specialist in orthopaedics; specialist in intensive care. In children trauma alarm, a specialist in paediatric medicine was also alerted.

Retrieval of patients

This is a retrospective cohort study of both adults and children admitted to the Emergency Department at Malmö University Hospital between 1 January 2011 and 31 December 2013, who underwent triage classification according to the METTS and classified as red alarm on arrival to the hospital and for children after April 2013 as the 'children trauma alarm'.

Patients were identified by a combined search of all the red alarms registered in the databases at the emergency and anaesthesiology department. The databases were searched for the keyword 'multi-trauma'. Beside these two registers, patients in the forensic autopsy register were searched for and identified using the code for 'unnatural death'. In addition, nine patients who were admitted to hospital were found exclusively within the forensic autopsy register. These nine patients were added to the studied cohort. Forty-eight individuals with major trauma from Malmö city were never triaged at hospital and were primarily transferred by the Police authorities to the Department of Forensic Medicine. These individuals were excluded from the study.

Patients were excluded for the following reasons: erroneous personal identification data ($n=3$); burns without any other traumatic injuries ($n=22$); hangings ($n=7$); drownings ($n=4$); asphyxia ($n=2$).

Follow-up information was collected for 3 months following the trauma event. Patient survival was checked in the Swedish Population Registry.

NISS

Injury severity score in each trauma patient was assessed retrospectively by NISS scoring. The abbreviated Injury Scale (AIS) classification system is a consensus-derived, anatomically based, 7-digit injury scoring system. The first six digits refer to a unique numerical identifier that designate the injured body region (out of nine regions), the type of anatomic structure and the specific anatomic structure; the seventh digit refers to an ordinal injury severity scale with categories ranging from 1 (minor injury), 2 (moderate injury), 3 (serious injury), 4 (severe injury), 5 (critical injury) to 6 (unsurvivable injury). NISS is calculated by summing the squares of the three highest AIS injuries, regardless of body region [7]. The NISS scale ranges from 1 to 75. NISS >15 and NISS ≤15 is defined as major and minor trauma, respectively.

In 31 patients, NISS score was calculated with the help of the forensic autopsy reports. Uncertainties in NISS scoring were resolved in study meetings.

Data collection

The data needed for the study were retrieved from a number of databases, besides the electronic patient record system (Melior). The data of the SOS alarm priority system, the ambulance driving time and the patients' medical condition such as prehospital death before arrival at hospital were retrieved from the scanned ambulance record. The data of the trauma patients being operated on within 10 hours after arrival to the hospital were retrieved from the operation planning program (Orbit). The radiological data for examinations performed within 10 hours after arrival was listed by a secretary working in the Radiological Department. All radiological examinations were divided into three different categories (trauma computer tomography (CT), which includes CT of the head, neck, thorax and abdomen, non-trauma CT or magnetic resonance (MR) of one body region or extra CT/MR of other body regions, any X-ray). The data on blood transfusions were retrieved from the database DoreMi from the Department of Transfusion Medicine. Data regarding intensive care were retrieved from the database PasIVA. The nationwide forensic case handling system Portalen was used to identify relevant fatal trauma cases subjected to a forensic autopsy.

Forensic autopsies

All autopsies were complete, covering all organ systems and documenting all injuries and disease findings and including histological examination of all

relevant organs. During a medicolegal autopsy the forensic pathologist determines, based on the characteristics of the case, if bodily fluids are to be sampled for toxicological analyses and which analyses to perform. The specimens are preserved in potassium fluoride, enzyme inhibitors and are shipped refrigerated (4°C). Toxicological analyses are performed at the Department of Forensic Toxicology in Linköping, Sweden. This department handles all toxicological analyses in medicolegal autopsies performed in Sweden. The preferred bodily fluids for sampling are blood from the femoral vein, urine and vitreous fluid. The toxicological analyses primarily cover pharmaceuticals, alcohols and illicit drugs. The regular screening method using blood from the femoral vein covers over 220 substances including a number of illicit drugs. Usually, both urine and blood from the femoral vein are screened for alcohols. Vitreous fluid is used if no urine is available and for certain specific analyses (e.g. glucose, insulin, potassium). Some substances are not detected by the routine screening protocols and need to be specifically addressed in order to be detected (e.g. synthetic cannabinoids, lithium, glycol, CO-haemoglobin, etc.).

Statistical methods

Data management and statistical analysis were performed using SPSS for Windows, version 20.0 (SPSS Inc, Chicago, IL). Differences in proportions were analysed using Kendall's tau-b test, chi-squared or Fisher's exact test and expressed in *p*-values and, when appropriate, in odds ratios (OR) with 95% confidence intervals (CI). Continuous variables were expressed in medians and interquartile ranges (IQR) and group differences were evaluated with the Mann-Whitney U test. *P*-value <0.05 was considered significant. Independent covariates associated with mortality were analysed in a multi-variable regression model and expressed in OR with 95% CI. Twenty patients with NISS >15 and 20 patients with NISS ≤15 were randomly generated from the SPSS program to be rated again, after a time interval of 3 months from the first rating, by the second NISS rater. The two raters were residents in emergency medicine and surgery, respectively. The inter-rater reliability (i.e. the consistency in the rating of subjects, although each subject is not provided exactly the same rating by all assessors) between the first and second NISS rater was evaluated with intra-class correlation (ICC) with 95% CI and a value of >0.7 was regarded as satisfactory [8]. The inter-rater agreement (i.e. the extent to which assessors make exactly the same judgement about a subject) was evaluated with proportional agreement and expressed in percentage of agreement. Inter-rater

Table I. Comparison of patient characteristics in patients sustaining major vs. minor trauma in patients triaged through red trauma alarm.

	Major trauma (NISS >15) (%)	Minor trauma (NISS ≤15) (%)	P
Patients	125	303	
Median age (IQR)	45 (24–62)	27 (15–46)	<0.001
Men/Women	86 (69)/39 (31)	211 (70)/92 (30)	0.86
Children (<18 years)	10 (8)	87 (29)	< 0.001
Elderly (≥65 years)	26 (21)	22 (7)	<0.001
Evidence of alcohol intake	13 (10)	37 (12)	0.85
Cause of trauma			
Accident	92 (73)	226 (75)	0.26
Self-inflicted	12 (10)	28 (9)	0.25
Assault/Homicide	16 (13)	49 (16)	0.38
Unclear	5 (4)	0 (0)	0.002
Mechanisms of injury			
Penetrating injury	19 (15)	63 (21)	0.18
Gun shot	8 (6.4)	18 (5.9)	0.86
Knife/Sharp objects	9 (7.2)	41 (14)	0.064
Other	2 (1.6)	4 (1.3)	0.62
Blunt injury	106 (85)	240 (79)	0.18
Fall accident	42 (34)	94 (31)	0.60
Traffic accident	54 (43)	104 (34)	0.084
Battery	2 (1.6)	10 (3.3)	0.30
Other	9 (7)	32 (11)	0.20
Trauma at work	6 (5)	11 (4)	0.57

agreement was graded as follows: lack of agreement (0.00–0.30); weak agreement (0.31–0.50); moderate agreement (0.51–0.70); strong agreement (0.71–0.90); very strong agreement (0.91–1.00) [9].

Results

Inter-rater reliability

The inter-rater reliability expressed as ICC coefficient between the first and second rater was 0.83 (95% CI 0.58–0.94) in 20 trauma patients categorized as NISS >15 by the first rater. The ICC coefficient between the first and second rater was 0.96 (95% CI 0.89–0.98) in 20 trauma patients categorized as NISS ≤15 by the first rater. The second rater upgraded one patient from NISS score 12 to 17 and downgraded one patient from NISS score 16 to 13. Agreement between raters according to group allocation NISS >15 and NISS ≤15 was 95% (19/20) and 95% (19/20), respectively.

Patient characteristics

Patients with major trauma were older, were less often subject to assault and battery and these patients were more often admitted with ambulance, compared to patients with minor trauma (Table I). Twenty eight (58%) out of the 48 elderly were involved in fall accidents ($p<0.001$). Road traffic accidents occurred

more often in younger adults between 19 and 64 years of age compared to elderly ($p=0.035$).

In-hospital management

Patients with major trauma more often underwent trauma CT, less often a non-trauma CT or MR, more often underwent an emergency operation, were more often treated at the intensive care unit (ICU) and more often received blood transfusion products, compared to patients with minor trauma (Table II).

Outcomes

Patients with major trauma had a longer in-hospital stay, were less often discharged to their home and were more often discharged to a rehabilitation centre or to a non-surgical ward, compared to minor trauma patients (Table III). Mortality was higher among major trauma patients. Forty-four (10.3%) patients of all 428 patients died within 3 months, but only 33 of these underwent forensic autopsy.

Forensic autopsy

Thirty-three patients underwent forensic autopsy and toxicological examination. Median age was 55 years (IQR 30–66) and 19 (58%) were men and 14 (42%) were women. The median NISS score was 50 (IQR 34–75). The patients died due to accidents

Table II. Comparison of in-hospital management in patients sustaining major vs. minor trauma in patients triaged through red trauma alarm.

	Major trauma (NISS >15)	Minor trauma (NISS ≤15)	P
	(%)	(%)	
Patients	125	303	
Radiology			
Trauma CT ^a	77 (62)	106 (35)	< 0.001
Trauma CT ^b	80 (64)	107 (35)	< 0.001
X-ray, any ^b	38 (30)	95 (31)	0.85
CT, any ^b	100 (80)	219 (72)	0.095
Non-trauma CT/MR ^b	36 (29)	121 (40)	0.030
Operation ^a	8 (6)	14 (5)	0.45
Operation ^c	46 (37)	57 (19)	<0.001
Surgeons ^a			
General	5 (4)	7 (2)	
Vascular	4 (3)	2 (0.7)	
Thoracic	1 (1)	0 (0)	
Neuro	1 (1)	0 (0)	
Orthopaedic	2 (2)	2 (0.7)	
Hand	0 (0)	3 (1)	
Otorhinolaryngologic	0 (0)	3 (1)	
Ophthalmologic	0 (0)	1 (0.3)	
Plastic	1 (1)	1 (0.3)	
ICU care	72 (58)	37 (12)	< 0.001
Assisted ventilation	51 (41)	20 (7)	< 0.001
Haemodialysis	1 (1)	0 (0)	0.29
Observation only	21 (17)	17 (6)	< 0.001
Blood transfusion ^d			
Red cell	61 (49)	26 (9)	< 0.001
Plasma	39 (31)	9 (3)	< 0.001
Thrombocyte	31 (25)	8 (3)	< 0.001

^aWithin 2 hours after arrival at hospital

^bWithin 10 hours after arrival at hospital

^cWithin 2 days after arrival at hospital

^dDuring first week after arrival at hospital

Table III. Comparison of outcomes in patients sustaining major vs. minor trauma in patients triaged through red trauma alarm.

	Major trauma (NISS >15)	Minor trauma (NISS ≤15)	P
	(%)	(%)	
Patients	125	303	
Median (IQR) in-hospital stay (days)	4 (0-14)	1 (0-4)	<0.001
Discharged from surgical ward			
Home	36 (29)	244 (81)	< 0.001
Rehabilitation	11 (9)	7 (2)	0.002
Non-surgical wards	40 (32)	46 (15)	< 0.001
Mortality			
In-hospital mortality	36 (29)	2 (0.7)	< 0.001
Mortality within 3 months	40 (32)	4 (1)	< 0.001
Forensic autopsy	32 (26)	1 (0.3)	< 0.001
Causes of death			
Intracranial injuries	22 (18)	0 (0)	0.11
Hypovolemic shock	7 (6)	1 (0.3)	0.57
Cervical columna injury	2 (2)	0 (0)	1.0
Aspiration	2 (2)	0 (0)	1.0
Flail chest	1 (1)	0 (0)	1.0
Fatty embolism	2 (2)	0 (0)	1.0
Infection	4 (3)	1 (0.3)	0.39
Natural death	0 (0)	1 (0.3)	0.091
Unknown	0 (0)	1 (0.3)	0.091

Table IV. Determinants for mortality at 3 months after red trauma alarm.

	Eligible patients (%)	Mortality at 3 months (%)	P-value	OR (95% CI)
All patients	428	44 (10.3)		
Age				
Elderly (≥ 65 years)	48 (11)	20 (41.7)	<0.001	10.6 (5.2–21.5)
Children (<18 years)	97 (23)	2 (2.1)	0.002	0.1 (0.03–0.6)
Female	131 (31)	17 (12.9)	0.22	1.5 (0.8–2.8)
NISS				
0–8	226 (53)	2 (0.9)		
9–15	77 (18)	2 (2.6)		
16–24	48 (11)	1 (2.1)		
25–40	46 (11)	18 (39.1)		
>40	31 (7)	21 (67.7)	<0.001	4.8 (3.2–7.1)
NISS $\geq 25^*$	77 (18)	39 (50.6)	<0.001	71.0 (26.4–191.0)
AIS $\geq 3^*$				
Head and neck	82 (19)	31 (37.8)	<0.001	15.6 (7.6–31.7)
Thorax	65 (15)	24 (36.9)	<0.001	10.0 (5.1–19.7)
Abdomen	28 (6.5)	14 (50)	<0.001	12.3 (5.4–28.3)
Extremities incl. pelvic skeleton	51 (12)	11 (21.6)	0.005	2.9 (1.3–6.1)
Shock at admission*	43/388 (11)	17 (39.5)	<0.001	10.1 (4.7–21.4)
Penetrating trauma	79 (19)	11 (13.9)	0.24	1.5 (0.7–3.0)
Gun shot	26 (6)	5 (19.2)	0.12	2.2 (0.8–6.2)
Traffic accident	160 (37)	15 (9.4)	0.63	0.9 (0.5–1.7)
Fall	132 (31)	16 (12.1)	0.40	1.3 (0.7–2.4)
Suicidal act	29/415 (7)	5 (17.2)	0.17	2.0 (0.7–5.6)
ICU stay	109 (26)	19 (17.4)	0.004	2.5 (1.3–4.7)
Trauma CT (within 10 hours)	187 (44)	16 (8.6)	0.30	0.7 (0.4–1.4)
Massive red cell blood unit transfusion (≥ 10 units)	22 (5.1)	5 (22.7)	0.048	2.8 (1.0–7.9)

(65%; 21/32), homicide (22%; 7/32) and suicide (13%; 4/32). The mode of death was unclear in one case. Fourteen out of 21 (66%) accidents were traffic accidents. The type of trauma was penetrating in nine (27%) cases and blunt in 24 (73%) cases. All seven murdered patients had penetrating trauma, of which four were gun shots.

Forensic toxicological examination

The median time from trauma to death was <1 day (range 0–32) in those 33 patients undergoing forensic autopsy and 24 (73%) died within the first day. Seventeen (52%) out of 33 patients were positive for any drug tested. The toxicological examinations were positive for ethanol in five (15%), anti-depressives in five (15%), sedatives in four (12%), analgesics in five (15%) and illicit narcotics in four (12%). The detected illicit narcotic drugs were amphetamine and tetrahydrocannabinol in two cases each. Opioids, tramadol, dextropropoxyphen and paracetamol were found in three, two, one and one case, respectively. Two patients who died after self-inflicted trauma were positive for anti-depressives. Eleven (33%) out of 33 patients were positive for more than one drug.

Factors associated with mortality at 3 months

Higher NISS score ($p < 0.001$) and higher age ($p < 0.001$) were associated with mortality. Severe head and neck, severe thorax, severe abdomen, severe extremity injuries, shock at admission, ICU stay and administration of massive red blood cell transfusion were associated with mortality at 3 months in a univariable analysis (Table IV). After entering NISS, age ≥ 65 years and shock at admission, in a multivariable regression model, NISS (OR 1.2; 95% CI 1.1–1.2), age ≥ 65 years (OR 33.3; 95% CI 9.0–122.9) and shock at admission (OR 5.7; 95% CI 1.5–22.1) remained as independent variables associated with mortality.

Discussion

The NISS score was an expected factor associated with mortality. In the present study, the unchanged mortality rate among patients with the NISS score 16–24 compared to those with the NISS score 9–15, however, questions the border definition between major and minor trauma. When NISS score was 25 and above, the mortality rate increased dramatically, however. The inter-rater reliability assessment of the

NISS scoring showed that scoring was relatively more reliable among patients sustaining minor compared to major trauma and that there was a very strong agreement between raters with regard to group allocation, major (NISS >15) or minor trauma (NISS ≤15). The inter-rater reliability was tested to be satisfactory, ICC 0.83, among major trauma patients in the present study, whereas another study has reported unsatisfactory reliability results in 50 Norwegian major trauma patients with predominantly blunt trauma [10]. The overall ICC values for the 10 AIS-certified trauma registry raters was 0.51 and only three raters reached an ICC value >0.7 when compared to reference standard [10]. The fact that coding in the present study was performed by only two raters with similar coding and clinical experience in emergency medicine may have resulted in a relatively congruent reliable coding. Nevertheless, it seems important to include an inter-rater reliability assessment of the NISS score when using NISS as a predictive tool in outcome studies, at least in studies on major trauma patients.

The NISS score system is an established model for predicting survival in patients after trauma [11,12]. As in the present study, NISS score up to 24 seems to be associated with a low mortality, around 2% [13], whereas mortality increases markedly with higher NISS scores. Overall NISS score, serious head and neck, thorax and abdomen injury, shock at admission and age were factors to be associated with mortality in the present study. These factors reflect, to various extent, anatomical injury, physiological reserve, age and comorbidity, respectively, which have been proven to effectively predict trauma mortality in a Scandinavian population with its typical spectrum of injury mechanisms [13]. The finding of a high prevalence of fall accidents among elderly and the prognostic significance of serious head and neck, thorax and abdomen injury on mortality has implications on preventive work.

It is rare that trauma surveys include both hospital and forensic autopsy and toxicological data. The present study included results of forensic autopsy, which strengthens the accuracy of data retrieved in terms of better coverage of all major traumas and better performance in NISS scoring when medical charts or clinical investigations at hospital were incomplete. In particular, a complete autopsy provides a more reliable tool for documenting traumatic injuries than clinical and radiological investigations alone.

The toxicological examinations showed that the deceased often were under influence of at least one drug. Interpretation of these toxicological results needs to be discussed in its proper perspective. As most trauma-related deaths in this study occurred within the first day, forensic toxicology data should be very useful, since drug clearance from the blood

circulation most likely has not occurred completely in most patients. Detected substances, illicit or not, may be of great value to identify socio-economic factors or circumstances to better understand risk factors associated with major trauma in the population studied, which in turn may be of use for better clinical management and for prevention of trauma. It cannot be excluded that detected anti-depressives, sedatives and analgesics in some patients might have been motivated from medical reasons and used in proper doses. Nevertheless, the toxicological results may imply that some patients might have suffered from certain diseases or conditions, such as depression, anxiety, insomnia or abuse, of importance for the occurrence of trauma. Previous larger forensic autopsy series in Sweden have shown that a large proportion of fatal traffic accidents, falls and homicides were positive for blood alcohol [14], particularly among men, and that the violent suicide method, jumping from heights, was related to finding of the illicit drug, tetrahydrocannabinol [15]. Whether the proportion of psychotropic drugs among individuals with fatal compared to non-fatal trauma differs is unclear, since there are, to date, no population-based studies available analysing this issue. There are very few prospective studies analysing the prevalence of drugs in trauma survivors, but available data after urine toxicology screening suggest that drug use is widespread in patients presenting with a moderate injury to an urban trauma centre [16] or after road accidents [17] and it has been suggested that drug testing in trauma patients should be performed routinely to exclude the possibility of influence of intoxication by psychotropic drugs. In patients tested positive for drugs, brief interventions can help to prevent future trauma [18].

In conclusion, the results confirm the expected risk factors for fatal trauma. The high prevalence of detected drugs among those undergoing forensic toxicological examination suggests that toxicology screening should be performed in all red trauma alarms, which has implications on prevention of future trauma.

Conflict of interest

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Study IV



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Necessity of including medico-legal autopsy data in epidemiological surveys of individuals with major trauma



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ABSTRACT

Background: It is rare that epidemiological surveys of patients with major trauma include both those admitted to the emergency department and those sent for medico-legal autopsy. The main aim of the present population-based study of major trauma was to examine the importance of medico-legal autopsy data.

Methods: A new injury severity score (NISS) > 15 or lethal outcome was used as criteria for major trauma and to identify patients at the emergency, anaesthesiology and forensic departments and/or being within the jurisdiction of the Malmö police authority and subjected to a medico-legal autopsy between 2011 and 2013. According to Swedish legislation all trauma related deaths should be reported to the police who refer these cases for medico-legal autopsy.

Results: Among the 174 individuals included, 92 (53%) died and 81 (47%) underwent medico-legal autopsy. One hundred twenty-six patients were primarily admitted to hospital and 48 died before admission to hospital and were sent directly for medico-legal autopsy. Forty-four in-hospital deaths occurred, of whom 33 (75%) were sent to medico-legal autopsy. In those sent directly to the department of forensic medicine the proportion of accidents was lower ($p < 0.001$), self-inflicted injuries higher ($p < 0.001$) and gunshot wounds higher ($p = 0.002$) in comparison with those sent to hospital. The most prevalent drugs detected by forensic toxicology screening in the 81 fatalities were ethanol (20%), sedatives (16%), anti-depressives (15%) and illicit narcotics (9%). Forty-four cases (54%) were positive for at least one drug, and twenty-eight cases (35%) were positive for two or more drugs. Factors associated with a lower rate of medico-legal autopsies among trauma-related deaths at hospital were high age ($p < 0.001$), lower NISS ($p < 0.001$), a longer duration between trauma and death ($p < 0.001$), falls ($p = 0.030$) and trauma-related infections ($p < 0.001$).

Conclusion: This population based study covering clinical and forensic data shows that more than half of the individuals sustaining major trauma died. An additional 25% of the in-hospital fatalities should have undergone medico-legal autopsy according to legislation, but did not. The high proportion of positive toxicological findings among fatalities examined at medico-legal autopsy implies that toxicology screening should be routine in major trauma patients, in order to improve treatment and prevention.

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Introduction

Injury is the largest single factor of death and severe disability in people under 40 years and the third leading cause of lost disability-adjusted life-years worldwide [1]. Trauma studies often

involve either case series with only in-hospital patients or only cases subjected to medico-legal autopsy. It is important to have an integrated and multi-disciplinary data collection system, otherwise significant loss of data may occur [2]. Combined analyses of both populations are rarely performed and the importance of including medico-legal autopsy data in epidemiological surveys of major trauma is unknown. Forensic experts are involved in the examination of traumatic death, by documenting the injuries, establishing the cause of death and the causality between the trauma and death [3,4]. The toxicological analyses are an

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important part of the forensic investigation and are primarily using blood from the femoral vein to detect pharmaceuticals, alcohols and illicit drugs.

Reporting standards of trauma makes data on injury severity in relation to outcome understandable and generalisable to other settings. The new injury severity score (NISS) [5] is a consensus-derived, anatomically based scoring system, which seems to perform superior to other scoring systems in mortality prediction of blunt injuries [6]. In Scandinavia, blunt trauma has been reported to occur more frequently than penetrating [7].

The main aims of this study of major traumas were to investigate the extent and characteristics of trauma fatalities not registered at hospital and subjected to a medico-legal autopsy and the cases treated at hospital but not subjected to a medico-legal autopsy.

Materials and methods

The study was approved by the Regional Ethical Review Board in Lund, Sweden (Dnr 2014/287).

Setting

The emergency department at Scania University Hospital in Malmö has a primary catchment population of 400,000 inhabitants. The emergency department is yearly visited by 84,000 patients, of whom 700 are trauma alarms. Individuals that die at the trauma scene or at hospital are transferred to the Department of Forensic Medicine in Lund, for a medico-legal autopsy requested by the police authority. Approximately 1000 medico-legal autopsies including toxicological analysis are performed annually at this forensic department. Among 590 medico-legal autopsies requested by the Malmö police authority between 2011 and 2013, 245 revealed the cause of death to be unnatural. Patients were excluded for the following reasons [8]: erroneous personal identification data ($n = 3$), burns without any other traumatic injuries ($n = 22$), hangings ($n = 7$), drownings ($n = 4$) and asphyxia ($n = 2$).

Retrieval of patients

This is a population based study of major trauma in both adults and children that were admitted to the emergency department at Malmö University Hospital or/and being within the jurisdiction of the Malmö police authority and subjected to a medico-legal autopsy at the Department of Forensic Medicine in Lund, between 1st January 2011 and 31st December 2013.

Definition of major trauma

Injury severity score in each trauma patient was assessed by new injury severity scoring (NISS) [9]. The Abbreviated Injury Scale (AIS) classification system is a consensus-derived, anatomically based injury scoring system with categories ranging from 1 (minor injury) to 6 (maximal injury). NISS is calculated by summing the squares of the three highest AIS injuries, regardless of body region. The NISS scale ranges from 1 to 75 (unsurvivable). Major trauma was defined as a NISS > 15 or as a patient sent for medico-legal autopsy after trauma.

Medico-legal autopsy and toxicology

During a medico-legal autopsy the forensic pathologist documents all external and internal injuries and signs of disease. Histological examination of selected organs is performed in the majority of cases. Based on the characteristics of the case, the

forensic pathologist determines if bodily fluids are to be sampled for toxicological analyses and selects analyses. The specimens are preserved by adding potassium fluoride and are shipped refrigerated (4 °C). Toxicological analyses are performed at the Department of Forensic Toxicology in Linköping, Sweden. This department handles all toxicological analyses in medico-legal autopsies performed in Sweden. The preferred bodily fluids for sampling are blood from the femoral vein, urine and vitreous fluid. The toxicological analyses primarily cover pharmaceuticals, alcohols and illicit drugs. The regular screening method using blood from the femoral vein covers over 220 substances including a number of illicit drugs. Usually both urine and blood from the femoral vein are screened for alcohols. Vitreous fluid is used if no urine is available and for certain specific analyses (e.g. glucose, insulin, potassium). Some substances are not detected by the routine screening protocols and need to be specifically addressed in order to be detected (e.g. synthetic cannabinoids, lithium, glycol, CO-haemoglobin etc.). The mean time from death to autopsy and collection of specimens was approximately 2–3 days. Based on the findings during the autopsy and the results of the additional investigations, the forensic pathologist determines the cause and manner of death.

Statistical methods

Data management and statistical analysis were performed using SPSS for Windows, version 20.0 (SPSS Inc., Chicago, IL). Differences in proportions were analysed using chi-squared or Fisher's exact test. Continuous variables were expressed in medians and interquartile ranges (IQR), and group differences were evaluated by using the Mann–Whitney U test. Cause-specific mortality ratios were expressed as number of deaths from major trauma per thousand forensic autopsies. Incidence rates were based on the number of overall, hospitalised and forensic autopsy-verified major trauma cases, respectively, and were expressed as number of cases per 100,000 person-years. Confidence intervals (CIs) were calculated assuming a Poisson distribution of events, using the normal approximation method for numbers > 15 . p -Values < 0.05 were considered significant. Twenty patients with NISS > 15 admitted to hospital and twenty individuals undergoing medico-legal autopsy were randomly generated from the SPSS programme to be rated again by the second NISS rater. Inter-rater reliability of NISS score among patients admitted to hospital and individuals undergoing medico-legal autopsy was evaluated by two clinicians and two forensic pathologists, respectively. The inter-rater reliability between the first and second NISS rater were evaluated with intra-class correlation (ICC) with 95% confidence intervals (CI). A value of > 0.7 was regarded as satisfactory [10].

Results

Inter-rater reliability of NISS score

The inter-rater reliability expressed as intra-class correlation coefficient (ICC) between the first and second rater was 0.83 (95% CI 0.58–0.94) in 20 major trauma patients admitted to hospital. Among trauma victims undergoing medico-legal autopsy, inter-rater reliability was evaluated in two different subgroups of 20 individuals, ICC was 0.92 (95% CI 0.80–0.97) and 0.96 (95% CI 0.90–0.98), respectively.

Epidemiology of major trauma

The overall incidence of major trauma was estimated to 14.5 (95% CI 12.1–16.9)/100,000 person years. The incidence of hospitalised major trauma patients was 10.5 (95% CI 8.7–12.3)/100,000 person

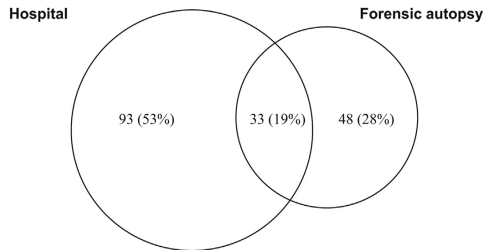


Fig. 1. Number of identified individuals sustaining major trauma in Malmö City.

years. The incidence of forensic autopsy-verified individuals sustaining major trauma was 6.8 (95% CI 5.3–8.3)/100,000 person years. The mortality rate among hospitalised patients was 34.9% (44/126). Deaths occurred in-hospital in 47.8% (44/92) and ex-hospital in 52.2% (48/92). The trauma-specific mortality ratio among those undergoing forensic autopsy was 137 (81/590) per thousand forensic autopsies.

Outcome of major trauma in Malmö City

The number of patients primarily admitted to hospital was 126 and 48 cases were sent directly from the accident site to the Department of Forensic Medicine. Among the 126 patients admitted to hospital, 33 fatalities were sent to the Department of Forensic Medicine (Fig. 1). Among all 174 individuals included, 92 (53%) died and of those 81 (47%) underwent medico-legal autopsy.

Characteristics of cases primarily referred to hospital or for a medico-legal autopsy

Cases not admitted to hospital but sent directly for a medico-legal autopsy had higher NISS-scores and the proportion of children, accidents and injuries caused by blunt trauma was

Table 1

Comparison of patient characteristics after major trauma in those primarily admitted to hospital versus those exclusively referred to forensic department.

	Admitted to hospital (%)	Forensic department (%)	p
Patients	126	48	
Median age (IQR)	45 (24–63)	49 (37–64)	0.097
NISS (median; IQR)	27 (18–39)	75 (45–75)	<0.001
Men/women	87 (69)/39 (31)	32 (67)/16 (33)	0.763
Children (<18 years)	10 (8)	0 (0)	0.044
Cause of trauma			
Accident	92 (73)	10 (21)	<0.001
Suicide	13 (10)	28 (58)	<0.001
Assault/homicide	15 (12)	10 (21)	0.13
Unclear	6 (5)	0 (0)	0.19
Mechanisms of injury			
Penetrating injury	19 (15)	18 (38)	0.001
Gun shot	8 (6)	11 (23)	0.002
Knife/sharp objects	9 (7)	6 (13)	0.26
Other	2 (2)	1 (2)	1.0
Blunt injury	107 (85)	30 (62)	0.001
Fall accident	42 (33)	16 (33)	1.0
Traffic accident	54 (43)	0 (0)	<0.001
Battery	2 (2)	0 (0)	1.0
Other	9 (7)	14 (29)	<0.001

lower compared to cases admitted to the hospital. In contrast, the proportion of self-inflicted injuries and penetrating injury was higher in cases sent directly for a medico-legal autopsy (Table 1). Traffic accidents were sent to hospital first. The median time between trauma to death was <1 day (range 0–0) in those primarily sent to Forensic Medicine ($n = 41$) compared to <1 day (range 0–77) in those primarily sent to hospital ($n = 44$). The time between trauma event and death could not be specified in days in seven fatalities. Among those admitted to hospital 57% died within the first day.

Medico-legal autopsy and toxicology

Forty-eight (27.6%) out of 174 cases of major trauma were not first admitted to hospital and only identified at the Department of Forensic Medicine. Among all 81 trauma fatalities subjected to a medico-legal autopsy, 38% of the deaths were caused by accidents, 41% were suicides and 21% were homicides (Table 2). The median time between trauma and death was <1 day (range 0–16) in those 72 patients where time was possible to specify in days. Sixty-four (89%) of these patients died within the first day. The highest proportion of detected drugs among fatalities were ethanol (20%), sedatives (16%), anti-depressives (15%) and illicit narcotics (9%) (Table 2). The median ethanol concentration was 1.2‰ (range 0.14–2.87). Forty-four (54%) out of 81 trauma fatalities were positive for at least one drug, and twenty-eight (35%) were positive for two or more drugs at the medico-legal autopsy. Among the 33 hospitalised patients who died and whom underwent forensic autopsy, five patients were administered *ketamine* ($n = 5$), *fentanyl* ($n = 2$), *morphine* ($n = 1$) and *diazepam* ($n = 1$) in hospital, and these pharmaceuticals were also detected at the forensic toxicological examination. None of these positive results were accounted for in Table 2. The positive ethanol result in three out of 81 patients was considered to have been partially or fully formed by decomposition.

Hospital fatalities referred or not referred to medico-legal autopsy

Table 3 shows a comparison between those hospital fatalities referred or not referred to medico-legal autopsy. Fatalities not subjected to a medico-legal autopsy were older, had lower NISS score, had a longer duration of time between trauma and death, were more often subjected to fall accidents and to a surgical procedure during the admission. Fatal traffic accidents were to a larger extent sent to a medico-legal autopsy. In the 11 cases not subjected to a medico-legal autopsy a fatal head injury was present in 9 cases and 7 were older than 80 years. In 2 cases the police was contacted by the hospital staff and a medico-legal autopsy was not considered necessary. Furthermore, one person survived the trauma and died of an unrelated disease (cancer).

Potential significant diagnostic errors as revealed by medico-legal autopsy

Thirty-three trauma deaths had received hospital care and were subjected to a medico-legal autopsy. Seventeen patients died at the trauma scene, pre-hospital care or the very early stages of hospital care and were not subjected to trauma computer tomography (CT) scan, whereas sixteen patients underwent both trauma CT and medico-legal autopsy. The medico-legal autopsy diagnosed two patients with fatty pulmonary embolism, which could not be diagnosed by the radiologist or the clinician, and were considered to have a direct impact on the fatal outcome. No other potential significant diagnostic errors of importance for the fatal outcome were detected at autopsy.

Table 2
Results of forensic autopsy and toxicology examination after fatal major trauma in Malmö citizens between 2011 and 2013.

Variable	N (%) of all eligible patients	N (%) of accidents	N (%) of suicides	N (%) of homicides
All patients	81	31 (38)	33 (41)	17 (21)
Toxicology				
Alcohol (Ethanol)	16 (20)	6 (19)	8 (24)	2 (12)
Anti-depressives	12 (15)	4 (13)	7 (21)	1 (6)
Analgetics	8 (10)	3 (10)	3 (9)	2 (12)
Sedatives	13 (16)	6 (19)	7 (21)	0 (0)
Benzodiazepines	9 (11)	4 (13)	5 (15)	0 (0)
Zolpidem/Zopiklon	3 (4)	2 (6)	1 (3)	0 (0)
Theralen/Atarax	2 (2)	0 (0)	2 (6)	0 (0)
Propavan	1 (1)	0 (0)	1 (3)	0 (0)
Illicit drugs	7 (9)	3 (10)	3 (9)	1 (6)
Tetrahydrocannabinol	5 (6)	2 (6)	2 (6)	1 (6)
Amphetamine	3 (4)	3 (10)	0 (0)	0 (0)
Opiates	2 (2)	1 (3)	1 (3)	0 (0)
Psicolin (psycodelic mushrooms)	1 (1)	0 (0)	1 (3)	0 (0)
GHB (gammahydroxybutyrate)	0 (0)	0 (0)	0 (0)	0 (0)
Kokainmetabolites	0 (0)	0 (0)	0 (0)	0 (0)
MDMA analogues (methylenedioxyamphetamine)	0 (0)	0 (0)	0 (0)	0 (0)

Discussion

The NISS scoring was a prerequisite to accurately define the present study population sustaining major trauma with

Table 3
Comparison between hospital fatalities referred or not referred to medicolegal autopsy within three months from trauma.

Variable	Referred (%)	Non-referred (%)	p
Patient characteristics			
Number of patients	33	11	
Men/women	19 (58)/14 (42)	8 (73)/3 (27)	0.37
Median age (IQR); years	55 (30–67)	84 (70–90)	<0.001
Median NISS (IQR)	45 (34–72)	25 (9–36)	<0.001
Median time, trauma to death (range); days	0 (0–32)	15 (0–77)	<0.001
Type of event			
Accidents	20 (61)	9 (82)	0.24
Suicide	3 (9)	1 (9)	0.60
Homicide	7 (21)	0 (0)	0.16
Unclear	3 (9)	0 (0)	0.56
Natural death	0 (0)	1 (9)	0.25
Trauma characteristics			
Blunt trauma	24 (73)	9 (81)	0.55
Penetrating trauma	9 (27)	2 (18)	0.55
Fall	9 (27)	7 (64)	0.030
Traffic accident	14 (42)	1 (9)	0.043
Intracranial injuries	21 (64)	9 (82)	0.26
Operated at hospital			
5 (15)	5 (45)	0.038	
Complications due to trauma			
Infections	6 (18)	6 (55)	0.022
Urosepsis	1 (3)	6 (55)	<0.001
Pneumonia	0 (0)	1 (9)	0.24
Superficial wound infection	0 (0)	3 (27)	0.011
Unclear infection focus	0 (0)	1 (9)	0.26
Pulmonary thromboembolism	1 (3)	1 (9)	0.45
Other complications	0 (0)	0 (0)	–
6 (18)	3 (27)	0.67	
Death cause			
Intracranial injuries	17 (52)	5 (45)	0.73
Hypovolemic shock	8 (24)	0 (0)	0.17
Cervical column injury	2 (6)	0 (0)	1.0
Aspiration	2 (6)	0 (0)	1.0
Flail chest	1 (3)	0 (0)	1.0
Fatty embolism	2 (6)	0 (0)	1.0
Infection	1 (3)	4 (36)	0.010
Natural death	0 (0)	1 (9)	0.25
Unknown	0 (0)	1 (9)	0.25

satisfactory results of inter-rater reliability among NISS scored hospital admissions. The excellent results of inter-rater reliability among NISS scored medico-legal autopsies makes comparative analysis between hospital admissions and medico-legal autopsies robust. As expected, the NISS score was higher among trauma fatalities referred directly to medico-legal autopsy compared to hospital admissions.

The present study clearly shows that a multi-disciplinary approach including data from both the clinical setting and from medico-legal autopsies is necessary in order to correctly evaluate epidemiological data in major trauma. Almost one third of patients who suffered major trauma died before admission to hospital and were never seen by clinicians. The summary report from the Victorian State Trauma Registry, Australia [11], shows that the incidence of individuals with major trauma in hospital and at forensic autopsy, was five and three times higher than the incidence in the present study, respectively. It might reflect differences in inclusion criteria, but nevertheless, incidence and deaths due to major trauma was clearly higher in the state of Victoria. The in-hospital death percentage was lower and ex-hospital death percentage was higher in Victoria, which might reflect differences in catchment areas and transportation systems.

Moreover, a number of characteristics differed between individuals admitted to hospital and deaths at the trauma scene whom were sent directly for a medico-legal autopsy. Penetrating trauma was encountered in a higher proportion among individuals sent directly from the trauma site to the department of forensic medicine. All individuals involved in traffic accidents were initially admitted to hospital, which might be explained by short transportation times to the emergency department. We speculate that the rate admitted to hospital is lower in the northern part of Sweden where the catchment areas are geographically larger [12].

Individuals subjected to a medico-legal autopsy toxicology screening were positive in a high proportion (54%). The high positive toxicology rate among fatalities has implications on prevention of future trauma, not only in trauma survivors, but also to the whole population in the longer perspective. Prospective studies indicate that drug misuse is widespread in trauma patients [13,14]. The results of the present study suggests that routine screening at the emergency department for drugs would be worthwhile to study if the proportion of drug prevalence is similar among trauma survivors with less severe injuries. If such a study can show a high percentage of drug positivity among trauma-related patients, set up of a follow up management algorithm may be facilitated and supported by the health care system. It has been

suggested that in patients tested positive for drugs, brief interventions can help to prevent future trauma [15]. In addition, it is very valuable for the physician in charge to be aware of any drug positivity when for instance assessing alertness in a multi-trauma patient or to avoid undesired effects when administering pharmaceuticals at the induction stage of anaesthesia in a patient in need of surgery.

It is known that nursing home deaths which fall under the jurisdiction of the coroner seldom undergo medico-legal autopsy in the United States [16] and that a similar situation exists in Sweden [17]. In one report, blunt force trauma was found to be a major autopsy finding (58%) in accidental nursing home deaths [16]. In the state of Victoria, Australia, only 38% of reportable in-hospital deaths who met the coroner's reporting criterion, were actually reported to the coroner [18]. The non-reported deaths to the coroner were more likely to be older, had a "not for resuscitation order" in place and died between 00:00 and 06:00. In similarity, the present study identified that patients with high age suffering from head trauma after fall were more likely not to be subjected to a medico-legal autopsy. It might be that elderly citizens with fall accidents might not follow the same strict management algorithm as younger individuals. Hence, there is a great risk that the overall incidence of fatal major trauma in the present study is underestimated, particularly among the elderly, due to unrecognised fatal blunt injuries among elderly not undergoing medico-legal autopsy [19].

In Sweden [20] as well as in many countries around the world [18,21], deaths due to trauma are considered unnatural and legal provisions require that all unnatural deaths are reported to the legal authorities for a decision to undergo medico-legal post-mortem examination. Those eleven identified patients that sustained major trauma and died, but were not sent to medico-legal examination, were managed erroneously by the responsible physicians and/or the police authority. This negligence or lack of knowledge of the legislation has recently been brought to attention in the Swedish Medical Journal [17]. In an attempt to improve the quality of death certificates in Sweden, it has been suggested to change the appearance of the death certificate, to more clearly state that if the death was not exclusively caused by natural disease, the police authorities must be notified by the physician signing the certificate [22]. If coroners are to optimise their potential to contribute to public health and safety, doctors reporting deaths must understand which deaths are reportable.

In conclusion, this population-based study shows that nearly half of individuals sustaining major trauma died and underwent medico-legal autopsy and an additional 25% of those patients that died in-hospital should have undergone medico-legal autopsy according to the legislation, but did not. The high proportion of positive toxicological findings detected at medico-legal autopsy implies that toxicology screening should be routine in major trauma patients in order to be able to intervene and prevent future trauma in survivors.

Conflict of interest

We hereby disclose any financial and personal relationships with other people or organisations that could inappropriately influence the work.

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