Master's thesis SSYX04/2017

Prehospital transportation decisions for patients sustaining major trauma in road traffic crashes: a comparison between US and Sweden

Patrycja Kozajda
Magdalena Krawczuk

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Electrical Engineering
Division of Biomedical Engineering
Chalmers University of Technology

Gothenburg, Sweden 2017

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Patrycja Kozajda
Magdalena Krawczuk

Supervisor: Ruben Buendia, PhD, Department of Electrical Engineering, Chalmers University of Technology
Co-supervisor and Examiner: Stefan Candefjord, PhD, Department of Electrical Engineering, Chalmers University of Technology, MedTech West at Sahlgrenska University Hospital University of Gothenburg

Master's Thesis SSYX04/2017
Department of Electrical Engineering
Division of Biomedical Engineering
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Typeset in LaTeX
Gothenburg, Sweden 2017

Abstract

In 2012, road traffic crashes (RTCs) accounted for almost a quarter of injury deaths in the world. The World Health Organization (WHO) estimated that in 2013 RTCs killed 1.25 million people. Therefore, RTCs became the tenth leading cause of death in the world, and the leading cause of death among children and young people below the age of 45.

Currently in Sweden, there does not exist trauma care system similar to the system established in the US. However, University Hospitals in Sweden provide a high level of care comparable to trauma centers (TCs) in US. Thus, a comparison between Sweden and US, with a well established trauma care system, may contribute to establish major trauma destination policies in Sweden.

The data were selected from the National Automotive Sampling System - Crashworthiness Data System (NASS-CDS) and Swedish TRaffic Accident Data Acquisition (STRADA) database for US and Sweden, respectively. The data from RTCs that occurred from 2010 to 2015 were analysed. For the given years there were a total of 10 289 patients from RTCs reported by the police in US and 31 415 patients reported by police and hospitals in Sweden.

The chi-square test was conducted to test statistically significant ($p < 0.05$) differences between the proportion of patients sustaining minor trauma compared to patients sustaining major trauma, differences between the proportion of patients sustaining major trauma and transported to a TC versus a non trauma center (non-TC), for each country and between both countries. Furthermore, the chi-square test was performed to find statistically significant differences between the proportion of patients transported to TC versus non-TC for each ISS group. The variables that were analysed for both countries were sex, age and location (rural or urban area). In addition, an analysis of race and BMI level was conducted for the US. Due to lack of data, the analysis of race and BMI for Sweden was not possible.

The proportion of patients sustaining minor trauma and transported to TC were 55.7% and 19.1% in US and Sweden, respectively. The proportion of patients sustaining major trauma and transported to TC were 87.6% in US and 31.9% in Sweden.

The conducted study indicate that in Sweden many RTCs patients with severe injuries are transported to a hospital with a lower level of care. This may be caused by undertriage or by lack of formal designated trauma care system and major trauma destination policies in Sweden. The opposite situation is presented in US, where observed results indicate low undertriage but at the price of high overtriage, which may be linked to the field triage protocol where it is stated that "*When in doubt, transport to a trauma center*". This study offers a unique insight into the rate of prehospital transportation decisions for RTCs and points out the large differences between US and Sweden.

Keywords: trauma center, prehospital transportation decisions, major trauma, road traffic crashes.

Acknowledgements

We would like to express our gratitude to our supervisors, Stefan Candefjord and Ruben Buendia, whose encouragement, guidance and support from the initial to the final level enabled us to develop an understanding of the subject. The door to our supervisor's office was always open whenever we ran into trouble or had a question about our research or writing. Furthermore, we would like to thank our supervisor from Poland, Krzysztof Krzysztofowicz for making the impossible become possible. Lastly, we offer our regards and blessings to all of those who supported us in any respect during the completion of the project, and to all of those who supported us in our master thesis defense.

Magdalena Krawczuk, Patrycja Kozajda, Gothenburg, October 2017

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1
Introduction

In accordance with the medical dictionary, trauma is a physical injury caused by an external source, for instance motor vehicle collision [1]. Trauma is the most common cause of death among people under 45. It is a disease in society which is a large public-health problem [2–8]. In 1966, the two first trauma centers were created in San Francisco and in Chicago (US). It was a first step to organize major trauma care [9]. In 1971, the *American College of Surgeons Committee on Trauma* (ACS-COT) published criteria to create and categorize TCs [10,11]. To guarantee medical care at a high level, the most important thing is understanding of trauma triage criteria and protocols to classify patients to an appropriate level of a TC [12–15]. Reviewing a number of studies concerning the transportation of severely injured patients, concluded that patients transported to a proper TC have higher survivability of 25% compared to patients treated in a non-TC [8,15–18]. Prehospital transportation decisions are based on the field triage and are carried out by Emergency Medical Services. Paramedics make decisions at the scene of injury about whether patients need transportation to a TC or can be transported to a local Emergency Department [15]. Their decisions mainly depend on protocol criteria, prior experience and instincts.

2
Aim

The present study was designed to assess the proportion and the characteristics of patients sustaining minor and major trauma in RTCs and transported to either a TC or a non-TC in the US and Sweden, and to compare results from the countries. The rationale was to evaluate what the prehospital transportation decisions on the scene of accident were and to understand the rationality of the decisions in both countries.

3

Theory

3.1 Road safety

According to the *International Road Traffic and Accident Database* (IRTAD), the decline of fatal road accidents has been noticed in 32 countries around the world between years 2010-2014. However, the number of road fatalities increased in at least 19 countries in 2015. Road traffic injuries accounted for almost a quarter of injury deaths in the world (Figure 3.1). WHO estimated that in 2013 road crashes killed 1.25 million people and another 20-50 million suffered from non-fatal injuries. *Road Traffic Injuries* became the tenth leading cause of death in the world, and the leading cause of death among children and young people below the age of 45 [2–6,8]. It is predicted that with a continuation of current trend, road traffic injuries will be on the 5th place in the rank in 2030, unless immediate action is taken [6].

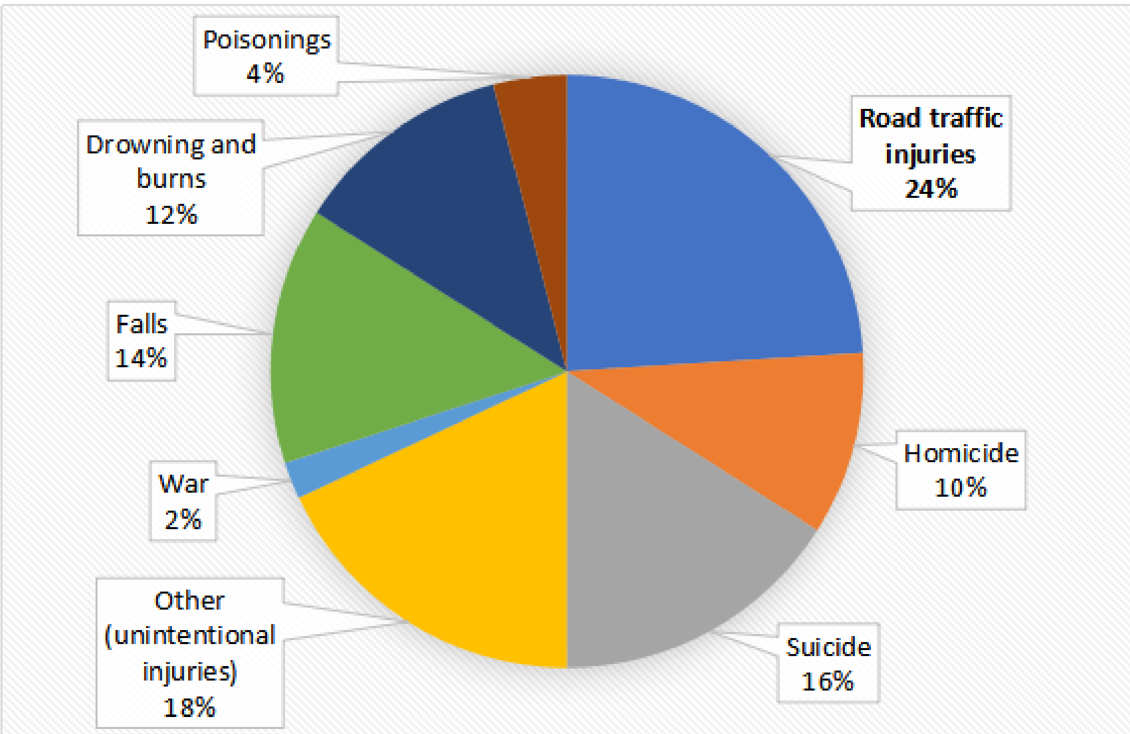

Figure 3.1: Causes of injury deaths in the world in 2012 [19].

3.1.1 Groups of risk of road crashes in the current situation

Young drivers are in an especially high risk group concerned in severe crashes. It is caused by lack of driving experience and specific characteristics for young age, like recklessness [20,21]. However, according to an overview for road safety performance in 40 countries from 2005 to 2014, fatalities associated with youth have decreased [22]. The second important risk group as a consequence of their physical frailty are elderly road users of age more than 75 [20]. Estimates by the WHO suggest that road traffic injuries are more frequent for males than females. Three out of four road deaths are among men [6].

The road safety statistics differ between all regions of the world. 90% of road traffic deaths appear in low- and middle-income countries (LMIC), which hold 54% of the world's registered vehicles. Among LMIC, high risk groups are pedestrians, cyclists and motorcyclists [6]. For these risk groups, road traffic deaths represent 23%, 22% and 4% for motorcyclists, pedestrians and cyclists, respectively.

Furthermore, the road safety is different depending on the type of road. Outside urban areas, severe crashes are prevailed by single vehicle conflicts. These crashes are mostly the result of inappropriate speeds, frequently subsequent to alcohol consumption or distraction due to other reasons than alcohol. On urban roads, important factors is a mass distinction as well as sensitivity of the road users along with speed and the vulnerability of vehicles. The safest roads are motorways, considering a combination of impermissibility of slow moving traffic and of high quality of road construction [20].

3.1.2 Traffic data collection

According to *International Association of Traffic and Safety Sciences*, RTC is an accident on a public or a private road that involves one or more vehicles in motion and appears in destruction to object and/or injury to people [23]. The definition of road death, introduced by the *United Nations Economic Commission for Europe* (UNECE), is a casualty who dies directly on a crash scene or within 30 days after an accident, excluding suicides [23].

For several reasons, crash statistics are repeatedly incomplete as a result of underreporting. The group of crash types preferred to register consists of crashes involving motorized vehicles to the detriment of cyclists and crashes concerning severely injured victims [21, 24]. The higher the severity of injuries, the lower the underreporting [20, 21].

Diversity of data collection procedures, data quality and completeness occurs among countries. These factors cause complications during comparison of the data. [22]. Nowadays, plenty of international actions are being developed to improve the availability and comparability of crash data collections [21,22]. Analysis and comparison of data about safety situation between different countries can contribute to establish leading policies in the concerned countries [25].

3.1.2.1 Traffic data collection in US and Sweden

National Automotive Sampling System - Crashworthiness Data System (NASS-CDS) is a national crash data collection program sponsored by the *U.S. Department of Transportation* and operated by the *National Highway Traffic Safety Administration* (NHTSA). The NASS-CDS includes traffic crash data collections on a random sample of crashes, which have been achieved at 24 geographic sites spread in central cities, suburbs and other locations. The geographic sites are called Primary Sampling Units (PSUs) in the US since 1979. The specific information about motor vehicle crashes involving passenger cars, vans and light trucks is reported by the police. Cyclists and pedestrians are reported only if a motor vehicle is involved in a crash. NASS researchers list and select accidents to be studied. They are allowed to gather police reports referring to selected accidents. Trained researchers continue an investigation on the site by interviewing victims and reviewing medical records to establish the severity of injuries. Injuries are coded according to the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) [26, 27]. AIS and ISS are described in subsections 3.3.1 and 3.3.2.

Swedish TRaffic Accident Data Acquisition (STRADA) is a national crash data information system including data on traffic crashes and injures in Sweden. The police and the hospitals are involved in the data collection for STRADA at the scene and in the emergency room, respectively. Police officers fill in a basic form including information about an accident place, time, causes, speed limit, vehicles etc. and several facts about the injured persons. Within the hospitals one form for each injured person is filled with information about diagnosis. Since 2003 a registration in STRADA is mandatory for police by regulation, while it is voluntary for hospitals, however economically compensated by the *Swedish Transport Agency* [28].

3.1.3 Road safety situation in US and Sweden

The road safety is characterised as a relation between the number of fatalities or injuried per year and the number of inhabitants. Fatalities per 100 000 inhabitants are represented as a mortality rate and injuried per 100 000 inhabitants are represented as a morbidity rate [20, 25]. These rates help to analyse the road safety situation in various countries or to compare road crash injuries with other diseases and threats [20].

In the United States, the motor vehicles are the most common form of transportation. Vehicle road crashes were the leading cause of death for young people ages 16-23 years old in 2015. 32 166 persons were fatal due to road crashes in US in 2015, 2 110 persons more than in 2014. However, from 2006 to 2014 a decreasing trend in killed and injured in motor vehicle accidents has been noticed [29].

The number of deaths in road crashes in 2015 was the lowest since 1940s in Sweden [30]. 259 persons sustained fatal injuries in road crashes in Sweden in 2015, 11 persons less than in 2014 [22]. Sweden is placed as one of the top scoring countries worldwide, where the mortality rate is less than 4.0 [20]. The figure 3.2 presents how Sweden and USA are ranked in terms of road mortality rates against other countries in the world in 2014 [22]. Table 3.1 presents the number of RTCs, number of deaths and number of injured in RTCs in US and Sweden in 2015.

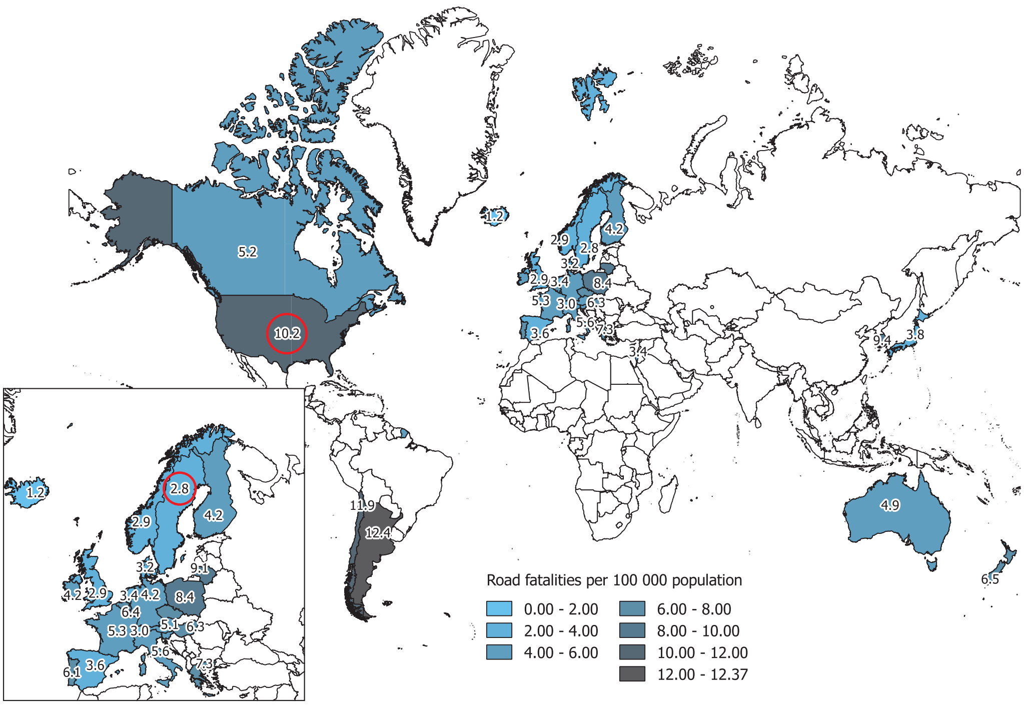

Figure 3.2: Road deaths per 100 000 inhabitants in 2014. Reprinted from Forum, I.T. (2016). Road Safety Annual Report 2016. OECD Publishing with permission from OECD Publishing.

Table 3.1: Comparison of RTCs records between US and Sweden in 2015 [29–31].

	US	Sweden
Number of RTCs	6 296 000	14 672
Deaths	35 092	259
Injured	2 443 000	19 643
Road deaths per population 100 000	10.9	2.6
Road injured per population 100 000	761.3	149.7

3.1.4 Road safety plan for the future

It has been noticed that the majority of countries put emphasis on an improvement of road safety [20]. Targets of global *Plan for Decade of Action for Road Safety 2011-2020* are to save 50 million people with serious injuries, 5 million lives and US$5 trillion [32]. The Swedish plan is to decrease fatalities by 50% and severely injured by 25% between 2007 and 2020 [22]. According to the brochure *Decade of Action for Road Safety, 2011–2020: Saving millions of lives* published by WHO, one of the most important pillars with developing progress in the road safety is post-crash response. The post-crash response is meant by appropriate first emergency and longer-term treatment and rehabilitation for crash victims. The good quality of prehospital care system, which occurs in early stages of emergency treatment, can have great influence on the lives of injured people in RTCs [32].

3.2 Trauma care system

In accordance with the medical dictionary, trauma is a physical injury caused by an external source, for instance motor vehicle collisions [1]. In the US trauma is the second most costly disease, just after heart disease [3, 4]. Trauma system is a complex structure created to provide appropriate medical care to severely injured patients [33–35]. Integral parts of trauma system are Emergency Medical Service and TCs. Emergency Medical Service "*refers to rescue and emergency services that provide medical response to injured people at the site of the accident*" [36]. TC is defined as "*a specialized hospital that is designed to provide diagnostic and therapeutic services for patients with traumatic injuries*" [37]. The main purpose of a trauma care system is to properly match the severity of the injury of the trauma patients to the suitable level of care which is shown in the figure 3.3 [2,4,12,13,33,38].

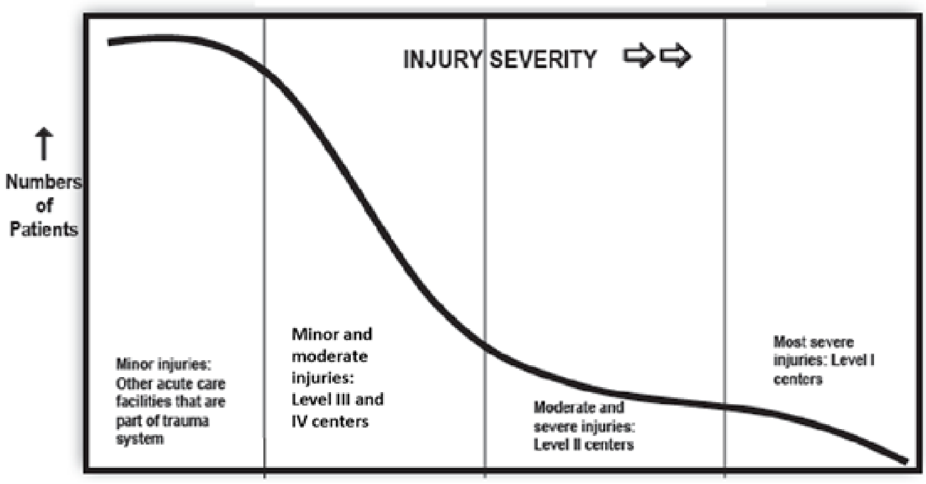

Figure 3.3: The Trauma System. Reprinted from American College of Surgeons. Committee on Trauma. (2014). Resources for optimal care of the injured patient. American College of Surgeons with permission from American College of Surgeons

A good organized trauma system provides transport of severely injured patients to level I or level II TCs. Those with modest injuries receive treatment at level III or non-TCs (explained in subsection 3.2.2) [2, 16]. The most important function of a good trauma system is correct field triage which, in combination with transport to a proper TC, will optimize survival outcomes [12]. Several studies indicate that TCs level I and II substantially decrease mortality for severely injured patients [3, 8, 38].

3.2.1 Prehospital transportation decision

Prehospital patient triage is carried out by Emergency Medical Service based on severity and injury type [13,39,40]. It is well known that prehospital intervention is a key for suitable treatment of injured patients [3,12,38]. To guarantee medical care at a high-level, it is crucial to understand the trauma triage criteria and protocols. With this knowledge, patients can be classified to appropriate level of TC [12–15]. It is not an easy task, because signs of severe injuries may appear with time.

Although, Emergency Medical Service uses field triage guidelines, decisions are made by paramedics under the influence of stress and time limit, which often results in undertriage or overtriage of patients (explained in subsection 3.2.4).

3.2.2 Levels of trauma centers

To distinguish levels of TCs in hospitals, the ACS-COT defined criteria according to the hospital resources and accessible expertise [4, 8, 10, 12, 17, 18, 33, 38, 41]. Four levels of TCs are differentiated. Level I trauma hospitals provide extensive level of surgical care for the most severely injured patients. They possess the most trained emergency physicians, anesthesiologists, specialised surgeons, nurses, and medical personnel, who are able to initiate resuscitation and carry on an operation instantly after arrival of the patient to the emergency department [4, 8, 12, 33]. The level I TC requires certain volume of injured patients to support proper education for medical personnel [12]. More strict research requirements and educational training for employees for level I TC compared with level II TC is the significant dissimilarity between those levels [8]. Level II TC can play different roles in urban and rural areas. In urban areas, it can work in cooperation with a level I TC to provide a 24-hour/7-day per week trauma care support [12, 39]. The cooperation allows for easy flow between hospitals to provide medical care at the highest level [12]. In rural areas, level II or even level III TCs operate as the lead TC [12]. Generally, in level III TC, full accessibility of physicians is not provided, but they have resources for emergency resuscitation, surgery, and intensive care for most trauma patients [12, 33, 39]. Level IV TC expand the trauma system to geographically isolated, and frequently medically forgotten rural areas, and serve as an initial treatment of patients with transfer to a higher level of care when necessary [4, 12, 33]. Usually, those centers provide a well-organized resuscitation team to resuscitate and stabilize patients, but they do not have continuous access to surgical resources [12, 33]. In the cases, when transport time to high-level centers is a crucial factor, the severely injured patients are also transported to non-TCs [12].

3.2.3 Advantages of transportation severely injured patients to high level trauma center

The literature has shown benefits of treating patients in a high-level TC compared with a non-TC. The patients treated in TCs were younger compared to patients treated in non-TCs [15, 18]. It should be pointed out that results of this investigation applies only to TCs in urban areas of America [18]. Mackenzie et al. [18] demonstrated a 25% decrease in odds of mortality related to appropriate triage of severely injured patients to a level I TCs in comparision with a non-TC. Similar conclusions in reduction in odds of mortality in properly triaged patients found in Vickers et al. [16]. In another two studies [8, 17], authors compared survival between level I and level II TCs. They demonstrated that patients with major trauma transport directly from the scene to a level I trauma hospital have lower mortality rate than those patients taken directly to a level II TC [8].

3.2.4 Undertriage and overtriage of injured patients

Patients with a major trauma who received care at lower level TCs than they need are undertriaged. Conversely overtriage means that minimally injured patients are transported to level I or level II TCs [2, 3, 5, 12, 42]. According to the ACS-COT, acceptable rates of undertriage and overtriage are 5–10% and 30–50% respectively [42–47]. In literature, authors agree that undertriaged patients were those with a major trauma (ISS >15) who were (1) treated and released from a non or level III TC, (2) admitted into a non or level III TC,or (3) died in the Emergency Department of a non or a level III TC [48, 49]. In examination conducted by Xiang et al. [48]in 2014, they investigated 36 395 major trauma patients in which 34.0% were undertriaged. They found that the lowest rate of undertriage was among adults between 18 to 54 years and the highest for patients above 54 years old. Furthermore, odds of undertriage was higher for females [48]. Interesting findings described in an article were related to reasons for undertriage of major trauma patients in the United States. Authors explained that not each state posses proper trauma care system, where all residents have access to all level of TCs within 60 minutes. Barsi et al. [45] focused on determining the risk factors associated with undertriage. They found that dementia was the most significant risk factor for patients with severe injuries due to difficulties with communication ability [45]. Another risk factors include: advanced age or female sex which was mentioned in other articles [48, 49]. The later was also related to higher probability of undertriage. Undertriage yields deprivation of access to TCs with a high quality equipment for patients with major trauma. On the other hand, the main result of overtriage is an increase of expenses because patients with minor trauma are unnecessary transported to a high level TC [46].

3.2.5 The amount and distribution of TCs in US till 2002

This chapter is written to show the approximate amount and distribution of TCs in US. Before further reading, a few important issues have to be highlighted. Firstly, during process of designation of TCs, states use ACS/COT criteria, but the definition of level differs between states. It means that states can modify and adjust criteria to own requirements (in other words, level I TC in one state does not necessarily correspond to level I TC in another state). Furthermore, authors excluded TCs which are designated only to treat children. Lastly, the distribution and number of TCs by level was examined by state, but not all TCs contribute to a state registry [10, 11].

TCs can be designated by the state or by the TC itself. In the first case, state and local agencies have a legal authority to create or categorize TCs according to the guideline published by ACS/COT in 1971 [10, 11]. If state does not have a formal trauma system, hospitals have to develop trauma units on their own initiatives and confirm their level for verification by ACS/COT [10, 11]. We found that counting of the number of TCs was conducted two times in the United States, in 1991 and 2002. To identify hospitals with a TC, it was necessary to survey emergency medical service directors by authors of the articles. Results of investigation in 2002 were an initial step to establish the national network of TCs. Since 1991 the number of states with formal trauma systems has increased from 21 to 35 [10]. Table 3.2 presents the amount of TCs regarding to the process of identifying TCs and level of a TC. As seen in Table 3.2, the number of hospitals which were formally designated has increased from 368 in 1991 to 1077 in 2002.

Table 3.2: The amount of TCs in USA in 1991 and 2002 [10].

Level of TC	1980 - 1991		1991 - 2002	
	formally designated	self-designated	formally designated	self-designated
I	126	39	149	41
II	160	49	234	29
III	64	12	244	7
IV	18	0	450	0
TOTAL	368	100	1077	77

3.2.6 Trauma care system in Sweden

In Sweden, the definition of a TC does not exist. There are 7 university hospitals which can be classified as a level I or level II TC according to a guideline published by the ACS-COT [50]. These hospitals do not meet the minimum requirement for a level I TC, but their research resources are better than for a level II TC according to the previously mentioned guideline. In the study conducted by Candefjord et al. [50], the following 8 hospitals were designated as TCs:

1. Astrid Lindgren Children's Hospital in Stockholm (part of Karolinska University Hospital)
2. Karolinska University Hospital in Solna/Stockholm
3. Uppsala University Hospital
4. Linköping University Hospital
5. Skåne University Hospital in Lund
6. Sahlgrenska University Hospital/Sahlgrenska in Gothenburg
7. Örebro University Hospital
8. University Hospital of Umeå

In this project we decided to follow the same approach as Candefjord and colleagues.

3.3 Trauma scoring system

Trauma scoring systems were introduced in early 1970s to describe the severity of injuries with a single numerical value [51]. The purpose of developing trauma scoring systems was to create a common language to help clinicians to communicate about trauma care [51–53]. Generally, the injury scoring process consists of dividing each injury into a set of injuries and measuring severity for each injury [54].

3.3.1 The Abbreviated Injury Scale (AIS)

The Abbreviated Injury Scale (AIS) is a global, anatomy-based scoring system for classifying the severity of injury. The AIS was developed in 1971 by the *Association for the Advancement of Automotive Medicine* (AAAM) in Illinois in USA. The system was introduced in order to provide researchers and crash investigators with a quantitative method for ranking injuries and simplify the description of injuries [55–57]. According to Gennarelli and Wodzin, the AIS became a standard system for crash organizations funded by the US Department of Transportation for universities and industry research organizations in Europe, Australia and USA [58]. The AIS severity scale ranges from 1 to 6. Each injury is classified for an anatomic region on a six-point scale [52, 53, 55, 56]. The higher value of the AIS, the more severe injury. Table 3.3 presents the AIS severity scale and a description for each value with an example of injury scored by specific AIS.

Table 3.3: Description of AIS scale [26, 59].

AIS score	Severity of injury	Example of injury
0	No injury specified	Shoulder pain
1	Minor	Wrist sprain
2	Moderate	Closed undisplaced tibial bone fracture
3	Serious, but not life threatening	Basal skull fracture
4	Severe, life threatening, but survival probable	Tear of thoracic aorta
5	Critical, survival uncertain	Complex liver laceration
6	Maximum, unsurvivable	Brain stem laceration

3.3.2 Injury Severity Score (ISS)

The Injury Severity Score (ISS) is the most popular and the oldest score derived from the AIS. The ISS provides an overall severity score of damage for patients with multiple injuries [52, 57, 60]. The AIS score (from minor injury = 1 to maximum injury = 6) is assigned to each injury and is allocated in body regions: head, face, thorax, abdomen, spine, extremities and external structures [52]. The highest AIS scores from the three most injured body regions are used to calculate the ISS. Only one injury per body region is permitted. If several injuries occur in one body region, the highest single AIS is chosen to calculate the ISS. The ISS ranges from 1 to 75 and for patient who obtained the AIS 6, the ISS of 75 is assigned automatically [52, 61]. The ISS is obtained by summing the squares of the highest AIS scores in each of the three most severely injured body regions [52, 57, 62]. An example of calculation of the ISS is described below [26, 63]:

$$ISS = 5^2 + 4^2 + 2^2 = 45 \tag{3.1}$$

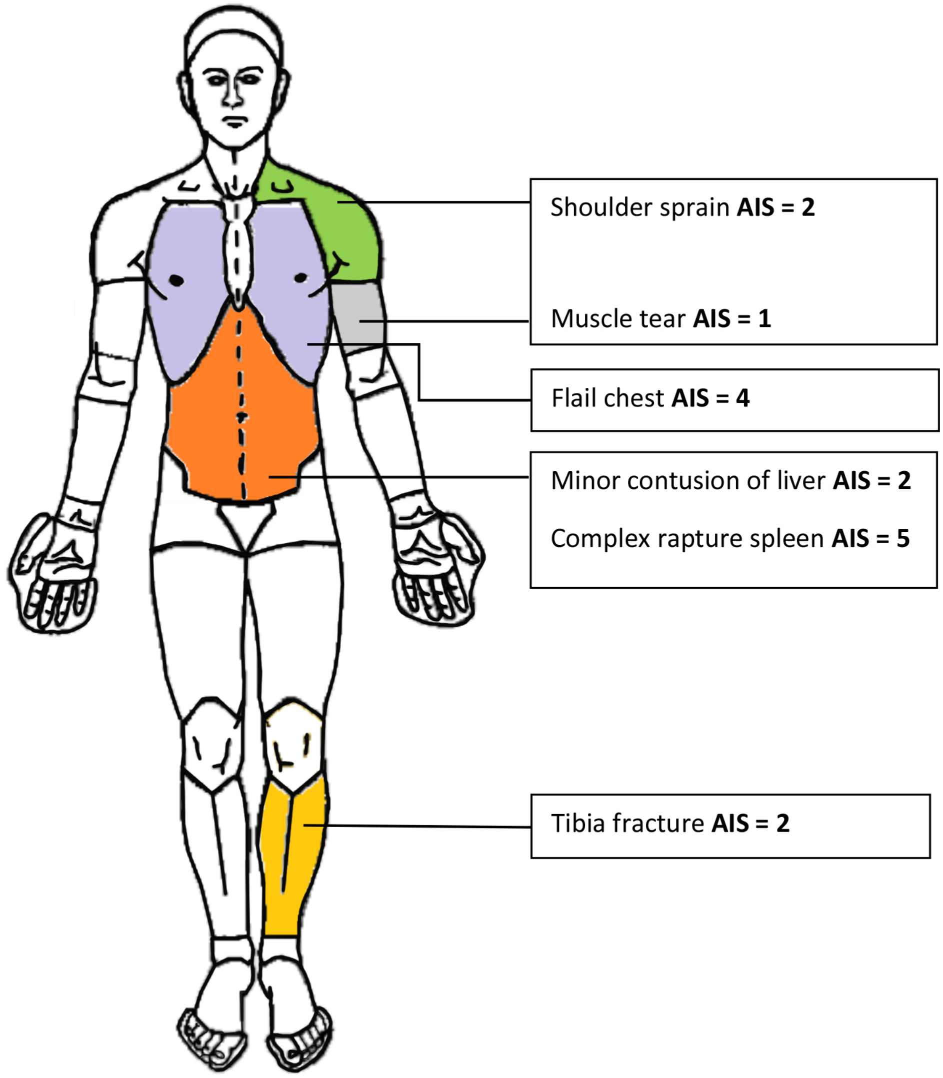

Figure 3.4: An example of an injured patient with assigned AIS for each injury [28, 63].

A patient from the above example sustained a critical injury to the spleen (AIS = 5), a severe injury to the thorax (AIS = 4) and other injuries elsewhere from moderate to minor (the highest AIS = 2).

Despite being commonly used, several limitations of ISS application exist. Firstly, the ISS takes into account only three most severe injuries sustained in different body regions. Hence, it may lead to underscoring the degree of trauma. The example is a patient who has more than one severe injury in either one body region or more than three regions. Secondly, since the ISS considers only one injury per region, multiple injuries to the same one body region are unable to be counted. Another drawback of the ISS is that two more severe injuries in one body region will be ignored in a favor of a less severe injury in other body region [26, 52]. The ISS can range from 1 to 75. The higher the score the greater trauma severity. Furthermore, the ISS of 75 is automatically assigned to patient who has injury with an AIS score of 6. Only one injury with the AIS of 6 is enough to set ISS of 75, and other injuries are not taken

Table 3.4: Characteristics of patient injuries [26, 52, 59, 63].

Region	Injury Description	AIS	Square Top Three
Head & Neck	No injury	0	
Face	No injury	0	
Thorax	Flail chest	4	16
Abdomen	Minor contusion of liver Complex rapture spleen	2 5	 25
Spine	No injury	0	
Lower Extremity	Tibia fracture	2	
Upper Extremity	Shoulder sprain Muscle tear	2 1	4
External	No injury	0	

into consideration [52, 61]. The ISS has been frequently used to set a threshold for the classification of major trauma [60]. The ISS of 15 has been used to distinguish minor and major trauma since 1980s [53, 60, 62]. Chawda et al. [52] reported that a patient who was assigned to the ISS greater than 15 requires care in a TC.

3.4 Statistics

It is important to apply appropriate statistical methods to analyse the data and draw conclusion from observations. Statistics is used when events are not completely predictable [64]. To analyse the data, an analysis plan should be created. Such plan should include information about type of presented data, how data was collected and what statistical tests were used. There are two ways of analysing the data: by descriptive statistics and by inferential statistics.

The aim of descriptive statistics is to summarise a sample, rather than to learn about the population, represented by the sample. The descriptive statistics include measures of central tendency, variability, relative position and relationship. To describe the relationship between analysed variables e.g. contingency tables are created (example in the section 3.4.3).

The inferential statistics is used to draw conclusion about the population from the differences and relations between study groups, which represent the population [65, 66]. In order to form a significant inference from the analysis, samples have to be representative and adequate to whole population [66]. The poor sample size might not be a reliable representation of the larger population. On the other hand, a study consisting of a large number of data points can be costly to conduct. The sample size is also regulated by the range of the diversity that needs to be found [65].

3.4.1 Hypothesis testing

If the differences between samples are recognised large enough to presume that real differences exist in the population, the next issue to consider is “What is the probability that our result is incorrect?" This question is a main concept in the inferential statistics [66]. To help to answer that question, statistical hypotheses are created. A statistical hypothesis is a description of a set of parameters of a population distribution. An issue is to develop a procedure which determines whether or not the values of random population samples are consistent with the hypothesis. The hypothesis is accepted if the sample is presumed to be consistent with this hypothesis; otherwise hypothesis is rejected [67, 68].

3.4.1.1 Null and alternative hypothesis

It is problematic to calculate straightforwardly the probability of a conclusion being true. Nevertheless, it is relatively simple to calculate the probability of the data being different from the "neutral" hypothesis, called null hypothesis (H0). The null hypothesis claims that there is no difference between the groups of population. The alternative hypothesis (H1) is opposite and claims that there is a difference between groups [64, 68]. The aim of a statistical test is to establish if the null hypothesis is consistent with the observed data. Thereby, the null hypothesis should be rejected only if the obtained data is very unlikely to be consistent with the null hypothesis. For example, if a difference between two means of the sample is not large enough to assure that there is a real difference in population, a statistical decision will be to fail to reject the null hypothesis (in other words, accept the null hypothesis). The other case, if the difference between two means of the sample is significantly large, the researcher will reject the null hypothesis. The rejection of the null hypothesis indicates that besides the chance, real difference between means exists in the population [64,66]. Phrase "the chance" is related to a significance level (α), which is chosen before data collection. The significance level is the probability of the study rejecting the null hypothesis, considering that it was true. A *p*-value is the probability of obtaining the effect the same as or more extreme than the observed result, assuming the truth of the null hypothesis. For instance, P value of 0.03 indicates that if the difference between study groups does not exist, a researcher obtain the same result or more extreme in 3% of studies due to random sampling error. The null hypothesis is rejected if the *p*-value is less than the significance level and the null hypothesis is accepted if the *p*-value is equal or greater than the significance level [64, 67] (Figure 3.5).

The smaller the significance level value a researcher has chosen, the stronger is the evidence against the null hypothesis. A data set is considered to be statistically significant if the probability of the null hypothesis having occurred purely by chance is less than the significance level. The most commonly chosen significance level is 0.05 (5%). However, if we are more certain of our alternative hypothesis, we can set the lower significance level of 0,01 (1%) or 0,001 (0,1%) [64].

3.4.1.2 Errors

With regard to the decision taken, several types of results are distinguished. There are two correct statistical decisions and two incorrect statistical decisions [66, 69]:

1. Correct inference (True Negative) - The null hypothesis is true in fact, a researcher assumed that it is true - fail to reject null hypothesis.

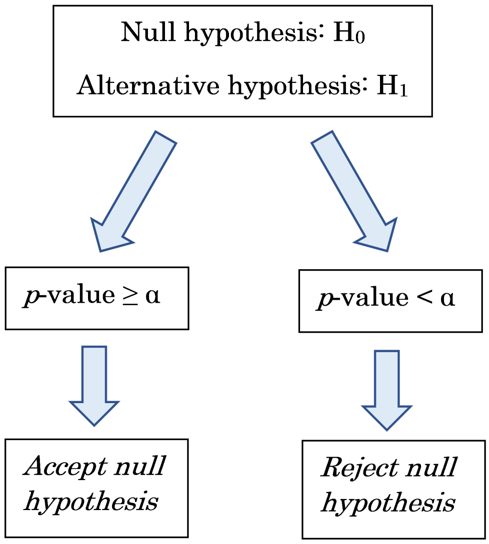

Figure 3.5: Scheme of rejection or acceptance of null hypothesis [64, 64, 66, 67].

2. Correct inference (True Positive) - The null hypothesis is false in fact, a researcher assumed that it is false - reject null hypothesis.
3. Type I error (False Positive) - The null hypothesis is true in fact, a researcher assumed that it is fail - reject null hypothesis.
4. Type II error (False Negative) - The null hypothesis is false in fact, a researcher assumed that it is true - fail to reject null hypothesis.

The case (3) when the test incorrectly estimated rejecting the null hypothesis, and it is true, is called a type I error. The type I error occurs when a researcher had an evidence from the sample that null hypothesis should be rejected, but in fact, based on an entire population there is an evidence that the null hypothesis was true and it should have been accepted. The other case (4), called a type II error, it is when the test calls for accepting the null hypothesis when it is false. The II type error occurs when a researcher concluded that an evidence do not detect a difference between the groups, but in fact, there is an evidence from the population that the null hypothesis was false and a researcher should have rejected it [66, 67, 69, 70].

3.4.2 Nonparametric statistics

Statistics texts present two types of statistic tests: parametric and nonparametric. The parametric test follows certain assumptions, called parameters, while the non-parametric tests do not demand the parameters or rules. However, the chapter is focused on a nonparametric tests. A reader can find information about parametric tests as well in the resources.

The nonparametric tests do not have the strict assumptions of parameters, they require some parametric counterparts, e.g. shape of the population's distribution. The distribution of values may be very skewed or non-normal for nonparametric methods. The approach of nonparametric tests forgoes the traditional establishment valid for parametric tests that values are limited to bell shape of the normal distribution. Nonetheless, shape of the distributions of these values within every group have to be similar [70–72].

Nonparametric statistics is a common choice for use in health care researches. One of the reasons is that the dependent variable can be categorical scale. The categorical data has usually two or more categories. Each study participant can be placed into one category [70]. We can distinguish a few types of categorical data: binary, nominal, ordinal and whole numbers [73]. Binary data represents only two possible outcomes, very often it is absence or presence of a property. Despite binary data is being coded numerically as 0 and 1, it expresses qualitative values, e.g. person's sex: female or male. Therefore, it is generally recognised as nominal data. Unordered and multicategorical data, called nominal data, could be classification of hair colour: blonde, brown, black, ginger, other. Ordinal data is a subset of categorical data type in which the categories have a natural ordering. Examples of ordinal data could be the categorisation of economic status in a logical order: low, medium, high [68, 70, 73]. Another assumption of nonparametric test refers to the sample size of the study groups. The sample sizes are allowed to be unequal for most of nonparametric tests whereas parametric tests require equal or approximately equal size of sample groups.

3.4.3 Chi-square test and post-hoc test

The chi-square test is nonparametric test, which permits a researcher to test hypotheses when variables are categorical type. Therefore, the test is often applied in medical research. There are several types of chi-square tests, however, the most well-known tests is the chi-square test of independence, also known as Pearson chi-square test. The chi-square test of independence is one of the most useful analysis tools to provide information about the nature of the data [73, 74]. The test provides information about if significant differences between two variables associated with the sample were observed [74]. The chi-square test is based on comparison the observed values with the expected values. If the difference between observed and expected values is large, it results in small p-value and therefore the rejection of the null hypothesis (rejection only if p-value$<\alpha$) [68].
The formula for calculating a Chi-Square is [74]:

$$\sum X^2_{i-j} = \frac{(O-E)^2}{E} \tag{3.2}$$

E = expected value O = observed value X^2 = the cell chi-square value $\sum X^2$ = formula to sum all the Chi-square values X^2_{i-j} = i-j is the notation to represent all the cells

An example of application the chi-square test is described in Figure 3.6 to investigate the relationship between type of heating (central heating versus coal or wood) and hay fever. The significance level was set to 0.05.
For each cell chi-square value is calculated and these values are summarised. The highest chi-square value of 3.48 occurs in the first cell ($11.3^2/36.7 = 3.48$).This cell has a much larger number of observed cases than would be expected if the type

Observed values

	Hay fever		
	Yes	No	*Total*
Central heating	48	569	617
Coal or wood	28	634	662
Total	76	1203	1279

Null hypothesis (H_0): there is no difference in the prevalence of hay fever between the two types of heating

Alternative hypothesis (H_1): there is difference in the prevalence of hay fever between the two types of heating

Expected values

	Hay fever		
	Yes	No	*Total*
Central heating	76*617/1279 = 36.7	1203*617/1279 = 580.3	617
Coal or wood	76*662/1279 = 39.3	1203*662/1279 = 622.7	662
Total	76	1203	1279

$$X^2 = \frac{11.3^2}{36.7} + \frac{11.3^2}{580.3} + \frac{11.3^2}{39.3} + \frac{11.3^2}{622.7} = 7.15$$

Degrees of freedom:
(num. of rows-1)*(num. of columns-1)
= (2-1)*(2-1) = 1

Figure 3.6: Example of chi-square test [68].

of heating has no effect to the hay fever. In the described example, cells in the second column (Hay fever = No) have chi-square values 0.22 and 0.23, respectively. Cells with chi-square value below 1.0 are interpreted as the number of observed and expected cases are approximately equal. Generally, the final chi-square value is not interpreted separately. The chi-square value is necessary to calculate more valuable piece of information: the p-value [74]. For 1 degree of freedom (degree of freedom is equal to the number of categories; in this case = 1) and value of chi-square 7.15, the p-value is equal 0.007. This means that the result is significant at $p < 0.05$. Thus, the null hypothesis should be rejected and alternative hypothesis should be accepted. Interpretation of p-value is that the probability of the result being consistent with the null hypothesis (there is no difference in the prevalence of hay fever between the two types of heating) is 0.7%.

The statistical analysis in this thesis was conducted by using chi-square test. There were several reasons for choosing this test. As a guide, statistical analyses in trauma literature were taken, where chi-square was used in similar analyses as in our thesis. Lee et al. [75], Palmer et al. [60, 76], Wong et al. [76], Candefjord et al. [50] used chi-square test in statistical analysis of trauma dataset.

To explain procedure of testing, the example from Palmer et al. [77] was taken into consideration. In the paper, gender was evaluated in ISS groups using the chi-square test. Patient age (less than 18 years) was compared in pair-wise in ISS groups using One-way ANOVA test with post-hoc Bonferroni correction (Table 3.5). Significant result from chi-square or ANOVA test is a global decision about differences between two groups. However, post-hoc multiple comparison was performed to conclude if differences were found between specific pairs. Bonferroni is one of the multiple comparison tests. If an overall error level α is set for the family of tests, the error level $alpha_{corrected}$ for each comparison in multiple k comparisons, is calculated $alpha_{corrected} = alpha/k$ for Bonferroni multiple comparison method. An example is that for a family of three tests, $alpha_{corrected} = 0.05/3 = 0.0167$ is set to control $\alpha = 0.05$ [78]. The Bonferroni comparison test is considered too conservative if the number of tests increases [78–80]. Hence risk of generating type II errors increases. Instead Bonferroni test, possibly less conservative alternative is Bonferroni-Holm method for multiple comparisons. This method is a sequentially rejective correction and strongly controls the family-wise error rate at level α (e.g. 0.05). All p-values from multiple k comparisons are sorted in order of smallest. If the first $p1$ is less than α/k (declared as significant) then the first null hypothesis is rejected and second $p2$ is tested. If $p2 >= \alpha/k$, the analysis is terminated and no further p-values are significant, otherwise the next p-value is tested. The procedure proceeds steps until null hypothesis is not rejected [78–80].

Table 3.5: Statistical tests performed across three groups of ISS [76].

	1: ISS 12-14	2: ISS 16-24	3: ISS >24	All patients
Gender				
Male	66	180	123	5202
Female	39	95	63	2975
Comparison (Chi-square)	p<0.8468			
Age (years)				
Average	10.47	8.93	8.81	7.64
Std deviation	4.23	5.02	4.86	4.70
Comparison (ANOVA)	$p < 0.0099$ 1 vs 2 & 1 vs 3			

Table 3.5 presents that there is no significant relation between gender and ISS group ($p > 0.05$) and there is significant relation between mean age and ISS group ($p < 0.05$) for pair ISS 12-14 and ISS 16-24 and for pair ISS 12-14 and ISS>24.

Assumptions that chi-square follows are described below [74]:
- The data should be counts or frequencies of cases rather than percentages, means.
- No assumptions of distribution of data exists (follow the normal distribution is not necessary).
- The variables have to be mutually exclusive. A specific subject can participate only in one category.
- Usually two categorical variables are used at the nominal level, but ordinal data may be used as well.
- No rule about limiting the number of categories exists, however, when more than 20 cells is applied, interpretation of the meaning of results is more difficult.

- The expected value can not be less than one and the expected values should be equal or more than 5 in at least 80% of the cells [74].

4 Methods

All statistical calculations were performed with Matlab (Version R2017A; MathWorks Inc., Natick, MA, USA). To confirm correction of calculations additional analyses were performed with Excel (Version 2016 Microsoft Office 365 ProPlus; Microsoft Corporation, Gates, Allen,WA,USA). Excel was used as well to analyse relations between variables from US and Swedish databases. This procedure was necessary to distinguish meaning of code values and decide which variables and which values of the code we focused on. Eight variables were analysed for US data and five variables were analysed for Swedish data (Figure 4.1). The reasons for the selected variables are described in the upcoming sections (4.1).

Table 4.1: List of analysed variables for US and Sweden.

	US	Sweden
Variable	ISS	ISS
	transportation (TC or non-TC)	transportation (TC or non-TC)
	age	age
	sex	sex
	location of road traffic crash	location of road traffic crash
	race	
	height	
	weight	

4.1 Data selection

4.1.1 US data

The data was selected from the *National Automotive Sampling System - Crashworthiness Data System* (NASS-CDS). 2015 Analytical User's Manual from NASS-CDS with description of variables was used to characterise the data. In this thesis, data from RTCs that took place from 2010 to 2015 were analysed. For given years, there were a total of 45 075 patients from RTC reported by the police. However, not all cases were analysed. Patients below age 18 (7202 patients), patients with missing value for Injury Severity Score (ISS) (16 285 patients) and patients for which transport to hospital was not provided or was unknown (10 759 patients), were excluded from analysis. Figure 4.1 shows stages of filtering the data set. The sample without missing data consisted of 21 048 patients. After the exclusion of patients with no medical transportation provided, the final sample consisted of 10 289 patients.

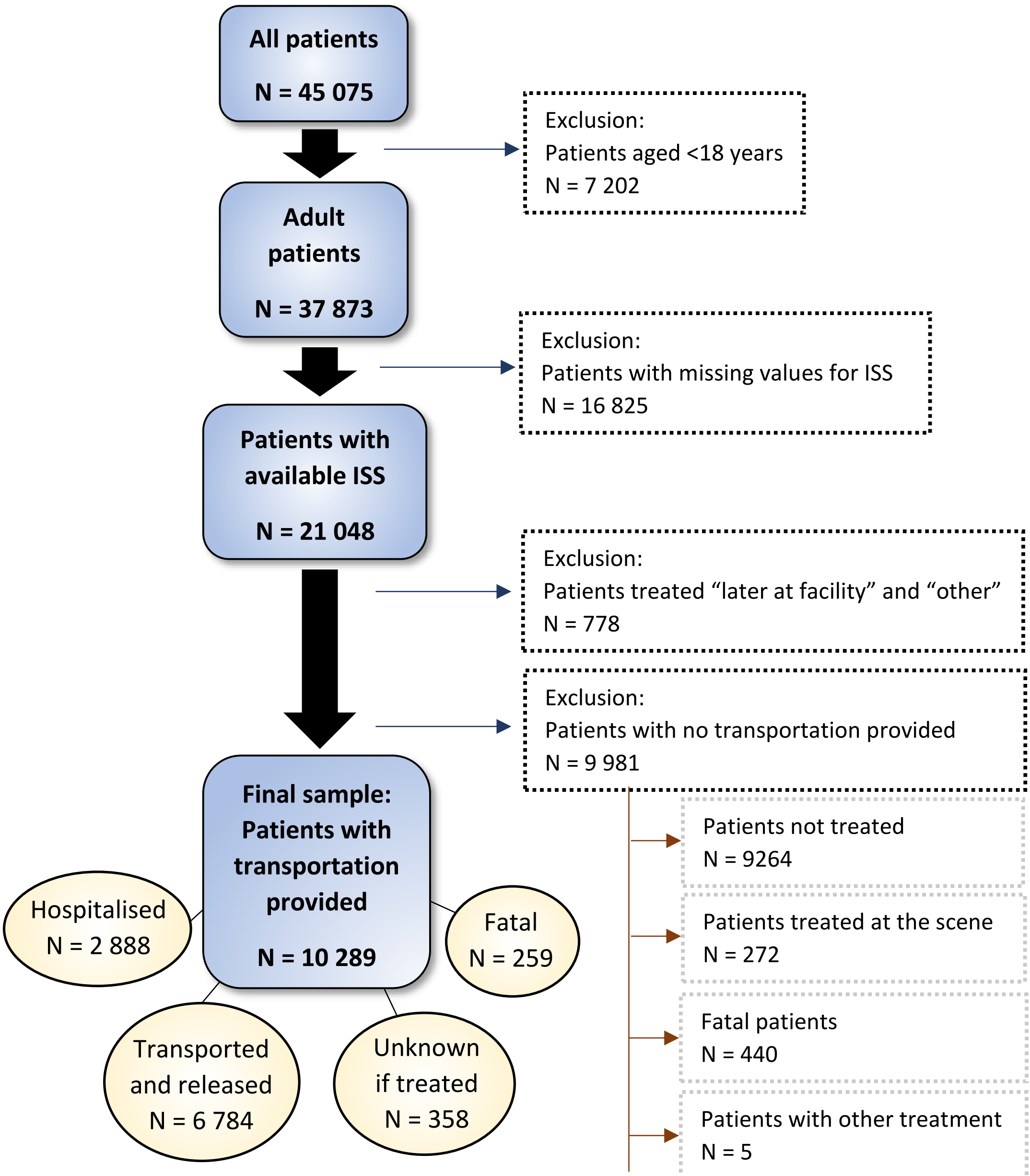

Figure 4.1: NASS-CDS data selection for given years 2010-2015.

4.1.1.1 Data filtering

To determine data selection, the variables for ISS (variable *ISS08*), type of medical facility initial treatment (variable *MEDFACIL*) and type of treatment (variable *TREATMNT*) from NASS-CDS were analysed. The variable *ISS08* refered to the ISS score from 2008 (currently the most updated format of ISS). *ISS08* represented the ISS score from 0 to 75 for each patient. Variable *MEDFACIL* referred to the type of medical facility initial treatment. Values of variable *MEDFACIL* are presented in Table 4.2. The data for patients with variable *MEDFACIL* = [1, 2, 3, 4] was defined as transported to a TC, a hospital, a medical clinic and a physician office, respectively. The data coded with *MEDFACIL* = [0, 5, 8] was not analysed, because patients were considered as there was no medical facility provided.

Table 4.2: Characteristic of medical facilities and the corresponding number of patients.

MEDFACIL code	Description	Number of patients	Percentage
0	non medical facility	9 981	47.4
1	trauma center	5 988	28.4
2	hospital	4 276	20.3
3	medical clinic	9	0.04
4	physician office	16	0.08
5	later at facility	772	3.7
8	other	6	0.03

There were 9 981 patients coded with the absence of medical facility *MEDFACIL* = [0], which was 47.4% of the sample. 9 264 (92.8%) of them were recognised as not transported and not treated (variable *TREATMNT* = [0]). These patients were assigned with ISS between 0 and 3 (very minor injuries). The variable *TREATMNT* = [1, 2] was used to code fatalities in the sample of 21 048 patients. The rest from 9 981 patients were fatal and not transported (440 patients from 9 981) or treated at the scene (272 from 9 981). There were 778 (3.7%) patients coded with *MEDFACIL* = [5, 80].

Although, almost half of the sample size (9 981 patients) was coded with *MEDFACIL* = [0], it had to be excluded from the analysis, because the purpose of the analysis was to compare patients transported to either the TC or to the non-TC by Emergency Medical Service.

4.1.1.2 Characteristics of patients

Sex of the patients was defined using a variable *SEX* in the NASS-CDS. As shown in Table 4.3, patients were coded from 1 to 6 where value of 1 was related to a male and values from 2 to 6 were related to a female. In this paper, division at a gestation period for females was not included. The missing data accounted for 9 patients, therefore the sample size was 10 280.
Age of the patients was defined using the variable AGE in the NASS-CDS. Age of patients was coded using values in years. Patients aged <18 were deleted from the data set. Age of patients was categorized into two groups, 18-55 and >55 according to articles [50, 52, 53, 55]. The missing data accounted for 40 patients, therefore the sample size was 10 249.

Location of RTCs was defined using the variable *PRIMARY SAMPLING UNIT NUMBER* in the NASS-CDS. As shown in Table 4.4, patients were coded for 24 numbers in three groups according to location of RTC: central city, suburban and

Table 4.3: Characteristics of the sex, description and corresponding code in the NASS-CDS.

Variable	Format name	Description	Code
Sex	SEX	Male	1
		Female-Not pregnant	2
		Fem-Preg 1st Tri	3
		Fem-Preg 2nd Tri	4
		Fem-Preg 3rd Tri	5
		Fem-Preg Unkterm	6

others. In the analysis it was decided to consider central city and suburban as urban areas and others as rural areas. There was not any missing data, therefore the sample size was 10 289.

Table 4.4: Characteristics of the geographical areas, description and corresponding code in the NASS-CDS.

Variable	Format name	Description	Code
LOCATION	PRIMARY SAMPLING UNIT (PSU) NUMBER	Urban	03, 05, 06, 08 09, 12, 41, 45 49, 72, 73, 74 75, 79, 81, 82
		Rural	02, 04, 11, 13, 43, 48, 76, 78

Race of the patients was defined using the variable *RACE* in the NASS-CDS. As shown in Table 4.5, patients were coded from 1 to 8, except 6. We decided to focus only for three race groups: White, Black and Asian. Groups coded by 4, 5, 7 and 8 were deleted because of an insignificant amount of data (n = 144). 2 280 patients were not assigned data, therefore the sample consisted of 7 865 patients.

Table 4.5: Characteristics of the race, description and corresponding code in the NASS-CDS.

Variable	Format name	Description	Code
Race	RACE	White	1
		Black	2
		Asian	3
		Native Hawiian/Other Pacific Islander	4
		American Indian/Alaskan Native	5
		Other	7
		No Driver Present	8

Height and weight of the patients were defined using the variable *HEIGHT* in centimeters and *WEIGHT* in kilograms in the NASS-CDS. In the paper, it was decided to use the variable *HEIGHT* and *WEIGHT* to count Body Mass Index (BMI). The motivation of choosing BMI to analyse was assessing if relations between obesity and severity of injury and between obesity and type of transportation exist. The sample size was 8 155, therefore the missing value accounted for 2 134. The mathematical formula for BMI is given below:

$$BMI = \frac{weight_k g}{hight_m^2} \tag{4.1}$$

Table 4.6: Characteristics of BMI.

BMI	Weight status
Below 18.5	Underweight
18.5-24.9	Normal (healthy weight)
25.0-29.9	Overweight
30.0 and above	Obese

4.1.2 Swedish data

The data was selected from the *Swedish TRaffic Accident Data Acquisition* (STRADA) database. In this thesis, data from RTCs that took place from 2010 to 2015 was analysed. For given years, there were a total of 39 733 adult patients (above aged 18 years old) from RTCs reported by the police and hospitals. However, not all cases were analysed. Patients for which transport to hospital was not provided or was unknown, were excluded from analysis. Data set did not include missing values. Figure 4.2 shows stages of filtering the data set. The final sample consisted of 31 415 patients.

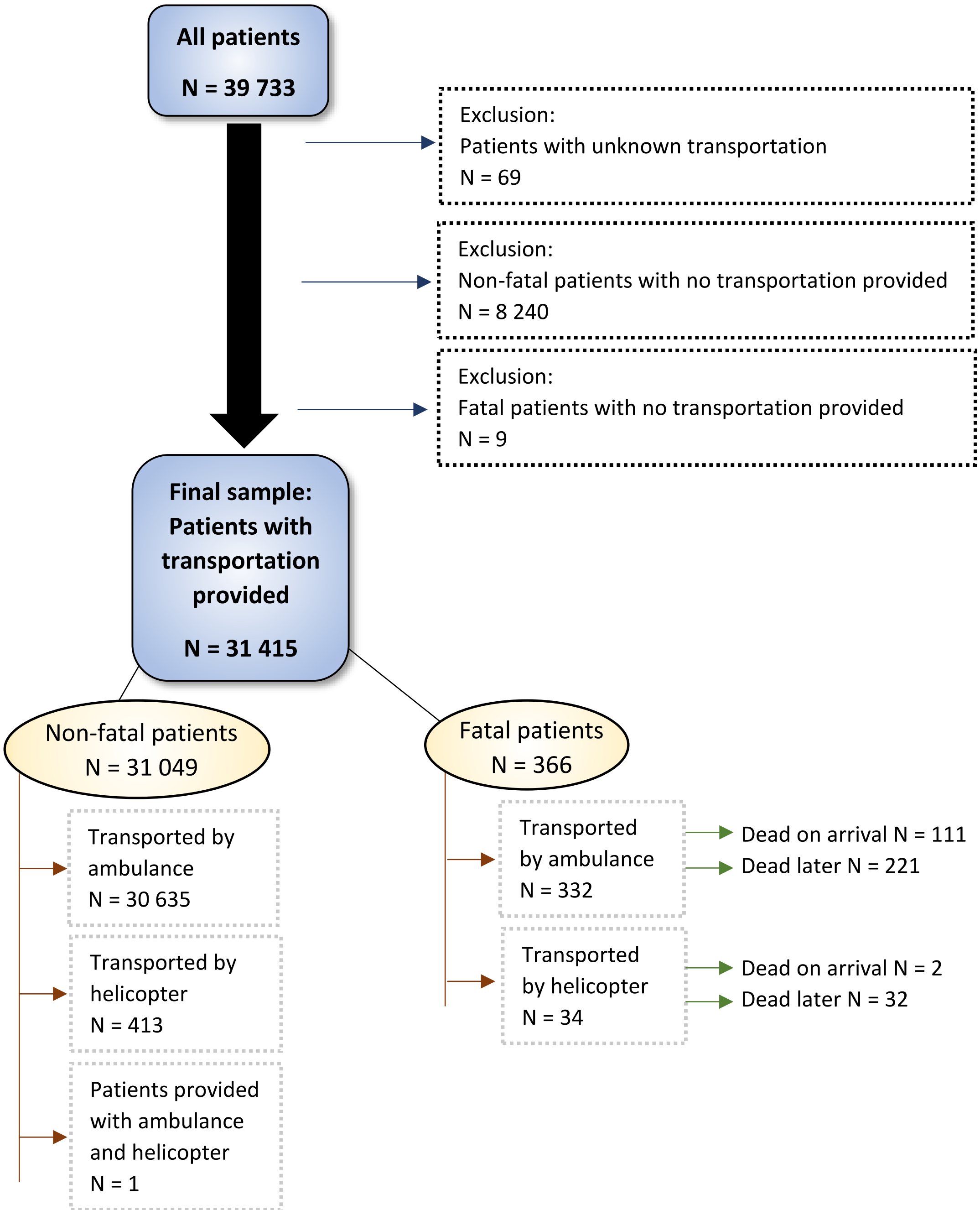

Figure 4.2: STRADA data selection for given years 2010-2015.

4.1.2.1 Data filtering

To determine data selection, the variables for ISS (variable *ISS*), type of medical facility initial treatment (variable *HOSPITAL*) and type of transport (variable *AMBULANCE* and *HELICOPTER TRANSPORT*) from the STRADA were analysed.

The variable *ISS* referred to the ISS score from 0 to 75 for each patient. Value of the ISS = [100] was a special case, because it referred to death of the patient on the site of an accident but injury was not reported. The variable *HOSPITAL* referred to the type of medical facility initial treatment. Hospitals designated as TCs, according to Candefjord et al. [50], were presented in subsection 3.2.6. The rest of values in variable *HOSPITAL* were assigned as non-TCs.

The variables *AMBULANCE* and *HELICOPTER TRANSPORT* indicated the presence or absence of medical transport. The presence of transport was described by *AMBULANCE* = [1] or *HELICOPTER TRANSPORT* = [1]. There was one case when ambulance and helicopter were provided to patient. In Table 4.7 this case was accounted as transported by ambulance as well as transported by helicopter. However, the differentiation between type of transportation (ambulance or hospital) was not analysed in the thesis, thus, patients was accounted once. Patients coded with the absence of medical transportation *AMBULANCE* = [0] and *HELICOPTER TRANSPORT* = [0] were excluded from the sample as well as patients with unknown type of transportation (*AMBULANCE* = [9, 99]; *HELICOPTER* = [9, 99]). There were 8 318 patients coded with the absence of medical transportation (8249 cases) or with unknown transportation (69 cases), which is 20.9% of the sample.

Table 4.7 presents number of patients transported to medical facility by ambulance or helicopter, patients not transported and unknown cases according to the variable *DEAD*, *AMBULANCE* and *HELICOPTER TRANSPORT*. There were 374 (0.9%) fatal crash patients coded with the variable *DEAD* = [0, 1, 2]. The rest of patients (31 049) coded with the variable *DEAD* = [9] was defined as a non-fatal. The motivation of assigning patients with *DEAD* = [9] as a non-fatal was the variable *DEAD DATE*, which did not include value in corresponding rows. Only 9 fatal crash patients (2.4%) from 374 were not transported to any medical facility and 4 fatal patients from those 9 were recognised as a dead on the arrival. Other 113 fatal cases recognised as a dead on the arrival were transported by ambulance (111 cases) or helicopter (2 cases).

Table 4.7: Characteristics of the treatment type and corresponding number of patients according to presence and absence of transportation.

<table>
<tr><th rowspan="2">STRADA variable</th><th rowspan="2">STRADA code</th><th rowspan="2">Description</th><th colspan="2">Transportation</th><th rowspan="2">No transp</th><th rowspan="2">Unknown</th></tr>
<tr><th>Ambl</th><th>Heli</th></tr>
<tr><td rowspan="2">DEAD</td><td>9</td><td>No dead</td><td>30 636</td><td>414</td><td>8240</td><td>69</td></tr>
<tr><td>0, 1, 2</td><td>Dead (Dead on arrival)</td><td>332 (111)</td><td>34 (2)</td><td>9 (4)</td><td>0</td></tr>
</table>

The explanation of shortcuts: Ambl - number of patients transported by ambulance, Heli - number of patients transported by helicopter, No transp - number of patients with no transportation provided

4.1.2.2 Characteristics of patients

Sex of the patients was defined using the variable SEX in the STRADA. As shown in Table 4.8, patients were coded using two values: 1 as a male and 2 as a female. There was not any missing data, therefore the sample size was 31 415.

Table 4.8: Characteristics of the sex, description and corresponding code in the STRADA.

Variable	Format name	Description	Code
Sex	SEX	Male	1
		Female	2

Age of the patients was defined using the variable *AGE* in the STRADA. Age of the patients was coded using values in years. Data set was included only patients aged >=18 years. Age of the patients was categorised into two groups, 18-55 and >55. There was not any missing data, therefore the sample size was 31 415.

Location of RTCs was defined using the variable *POPULATION CENTRE* in the STRADA. As shown in Table 4.9, patients were coded using two values: 0 as involved in a crash occured in urban areas and 1 as involved in a crash occured in rural areas. The unknown data accounted for 2 063 patients, therefore the sample size was 29 352.

Table 4.9: Characteristic of the location, description and corresponding code in the STRADA.

Variable	Format name	Description	Code
LOCATION	Population Centre	Urban	0
		Rural	1

Due to lack of the data in the STRADA datbase, the analysis of race and BMI could not be conducted.

4.2 Data analysis

The data was categorised into groups of ISS: 0, 1-3, 4-8, 9-15, 16-24, >=25. Levels are applied to observe the proportion of patients transported to a TC versus a non-TC for each ISS group. The motivation of categorisation into ISS groups was based on the study by Candefjord et al. [50]. However, in further analysis only two groups of ISS were analysed: minor trauma (ISS<15) and major trauma (ISS>15). We used the treshold of ISS = 15 to distinguish minor and major trauma, based on following studies: [50, 52, 53, 60, 62]. The chi-square test was conducted to test statistically significant ($p < 0.05$) differences between the proportion of patients sustaining minor trauma versus major trauma in US and in Sweden, differences between the proportion of patients sustaining major trauma and transported to a TC versus a non-TC in US and in Sweden. Furthermore, the chi-square test was performed to find statistically significant differences between the proportion of patients transported to a TC versus a non-TC for each ISS group. Reasons for choosing the chi-square test were the assumptions that chi-square follows (described at subsection 3.4.3). Table 4.10 presents all comparisons, which have been made for both countries. The chi-square test was applied as well to test statistically significant differences in the proportion of patients between US and Sweden (Table 5.1).

Table 4.10: Performed comparisons with the chi-square test for US data and Swedish data.

Comparison for two variables		Reference (link to the chapter)
Variable 1	Variable 2	
Six ISS levels	TC versus non-TC	Figures: 5.1,5.4, Tables: 5.2, 5.8
Proportion of patients aged >55 years	minor versus major trauma major TC versus major non-TC	Table 5.1
Proportion of males	minor versus major trauma major TC versus major non-TC	
Proportions of patients involved in crash in urban environment	minor versus major trauma major TC versus major non-TC	
Three races (white, black, asian)	minor versus major trauma major TC versus major non-TC	Tables: 5.5, 5.6
Four BMI levels	minor versus major trauma major TC versus major non-TC	Tables: 5.3, 5.4

The significance level (α) was set at the value 0.05. Consequently, our expectations that the differences existing in the sample exists in the population 95% of time (100-α)%. However, using lower α values (e.g. 0.001) decreases the possibility of making a type I error, but it increases the chance of making a type II error. The result of error II can be fail to accept a significant difference in the population. On the other hand, increase of the value of α (e.g. 0.1) can diminish the criteria for rejecting the null hypothesis [67, 87].
Holm-Bonferroni host poc testing followed the chi square test. Th Holm-Bonferroni multiple comparison was performed if the variable consisted of more than two categories and the result from the chi-square test was statistically significant ($p < 0.05$).

5

Results

The section present results for US and Swedish data analysis. Statistical summaries with the chi-square tests results were presented in Table 5.1 for US data and Swedish data.

Table 5.1: Statistical summary of the US and the Swedish (SE) data set (Full, consisting of both major and minor trauma patients), minor trauma cohort subset (Min) and the major trauma cohort subsets (Maj) transported to a TC (Maj TC) and transported to a non-TC (Maj non-TC), respectively.

Variable	Statistic	Unit	Country	Full	Min	Maj	Maj TC	Maj non-TC
Patients	Sum	No.	US SE	10 289 31 415	9 482 30 551	807 864	707 276	100 588
Patients	Sum	Pct.	US SE	100 100	92.2‡ 97.2	7.8 2.8	87.6 31.9	12.4$^{\diamond}$ 68.1
Age	Mean	Years	US SE	41.7 40.1	41.6 39.9	42.9 47.5	42.0 47.0	49.0 47.8
Age	Proportion of aged >55 years	Pct.	US SE	23.9 21.7	23.5‡ 21.2	28.0† 38.5†	26.3* 35.5	40.0$^{\diamond}$ 40.0
Sex	Proportion of males	Pct.	US SE	45.8 55.4	45.1‡ 54.9	54.6† 70.3†	54.6 71.4	55.0$^{\diamond}$ 69.7
Localisation	Proportion of urban environment	Pct.	US SE	67.4 29.2	67.2‡ 29.6	70.1 16.6†	75.0* 15.0	36.0$^{\diamond}$ 17.4

Daggers (†) and asterisks (*) indicate statistically significant differences ($p < 0.05$) between Maj and Min for country, and between Maj TC and Maj non-TC for country, respectively. Double dagger (‡) and diamond ($^{\diamond}$) indicate statistically significant differences ($p < 0.05$) between Maj and Min for both countries, and between Maj TC and Maj non-TC for both countries, respectively.

5.1 US

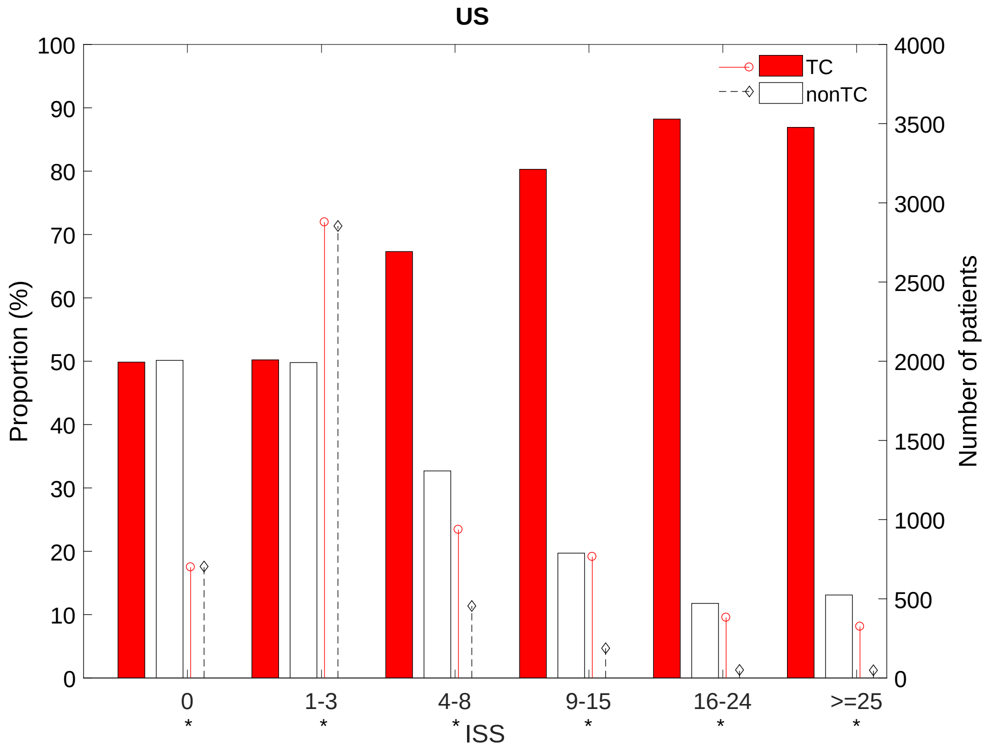

Figure 5.1: The proportion (bars, left-hand-side y -axis) and numbers (stems, right-hand-side y-axis) of all patients (n = 10 289) transported to a TC versus a non-TC for different ISS groups in US. The asterisks indicate that the proportion of patients transported to a TC versus a non-TC differs with the statistical significance for each ISS group ($p < 0.05$).

Table 5.2: The proportion and number of all patients (n = 10 289) transported to a TC versus a non-TC for different ISS groups in US.

	Number of patients		Proportion [%]		
ISS	TC	non-TC	TC	Chi-square	p-value
0	700	704	49.9	716.57	<0.00001
1 - 3	2 878	2 854	50.2		
4 - 8	937	455	67.3		
9 - 15	766	188	80.3		
16 - 24	382	51	88.2		
>25	325	49	86.9		

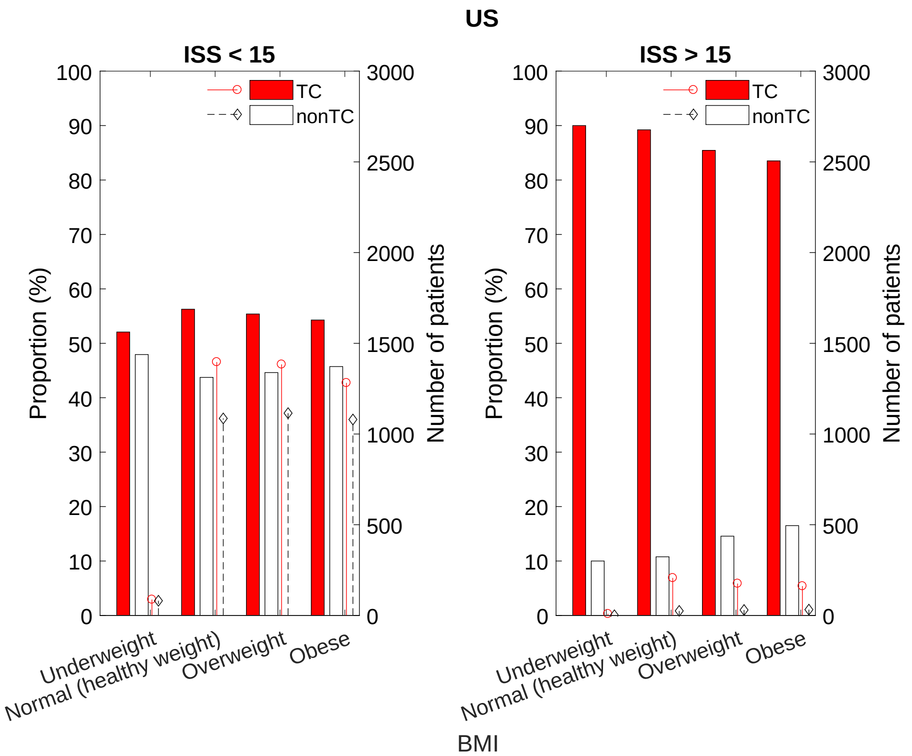

Figure 5.2: The proportion (bars, left-hand-side y -axis) and number (stems, right-hand-side y-axis) of all patients (n = 8 155) transported to a TC versus a non-TC for major and minor trauma in US according to level of BMI.

Table 5.3: The proportion and number of all patients (n = 8 155) transported to a TC versus a non-TC for major and minor trauma in US according to level of BMI. Differences between the proportion of patients sustaining major trauma and transported to a TC versus a non-TC were not statistically significant ($p > 0.05$).

BMI	Patients with minor trauma			Patients with major trauma		
	Number of patients [No.]		Proportion [Pct.]	Number of patients [No.]		Proportion [Pct.]
	TC	non-TC	TC	TC	non-TC	TC
Underweight	88	81	52.1	9	1	90.0
Healthy weight	1 397	1 086	56.3	207	25	89.2
Overweight	1 384	1 115	54.9	176	30	85.4
Obese	1 282	1 080	54.3	162	32	83.5

Table 5.4: The proportion and number of patients (n = 8 155) sustaining minor trauma and major trauma in US according to level of BMI. Differences between the proportion of patients sustaining major trauma versus minor trauma were not statistically significant ($p > 0.05$).

BMI	Number of patients		Proportion [%]
	minor trauma	major trauma	major trauma
Underweight	169	10	5.6
Healthy weight	2 483	232	8.5
Overweight	2 499	206	7.6
Obese	2 362	194	7.6

The differences between the proportion of patients sustaining minor versus major trauma for each BMI level were not statistically significant ($p > 0.05$) and the differences between the proportion of patients sustaining major trauma and transported to a TC versus a non-TC for each BMI level were not statistically significant as well ($p > 0.05$).

Table 5.5: The proportion and number of all patients (n = 7 865) transported to a TC versus a non-TC for major and minor trauma in US according to race. Differences between the proportion of patients sustaining major trauma and transported to a TC versus a non-TC were not statistically significant ($p > 0.05$).

RACE	Patients with minor trauma			Patients with major trauma		
	Number of patients		Proportion [%]	Number of patients		Proportion [%]
	TC	non-TC	TC	TC	non-TC	TC
White	2 702	2 379	53.2	446	65	12.7
Black	1 167	670	63.5	107	16	13.0
Asian	166	121	57.8	26	0	0

Table 5.6: The proportion and number of patients (n = 7 865) sustaining minor trauma and major trauma in US according to race. The proportion of patients sustaining minor versus major trauma for different races in US differ with statistical significance ($p < 0.05$).

Race	Number of patients		Proportion [%]
	minor trauma	major trauma	major trauma
White	5 081	511	9.1
Black	1 837	123	6.3
Asian	287	26	8.3

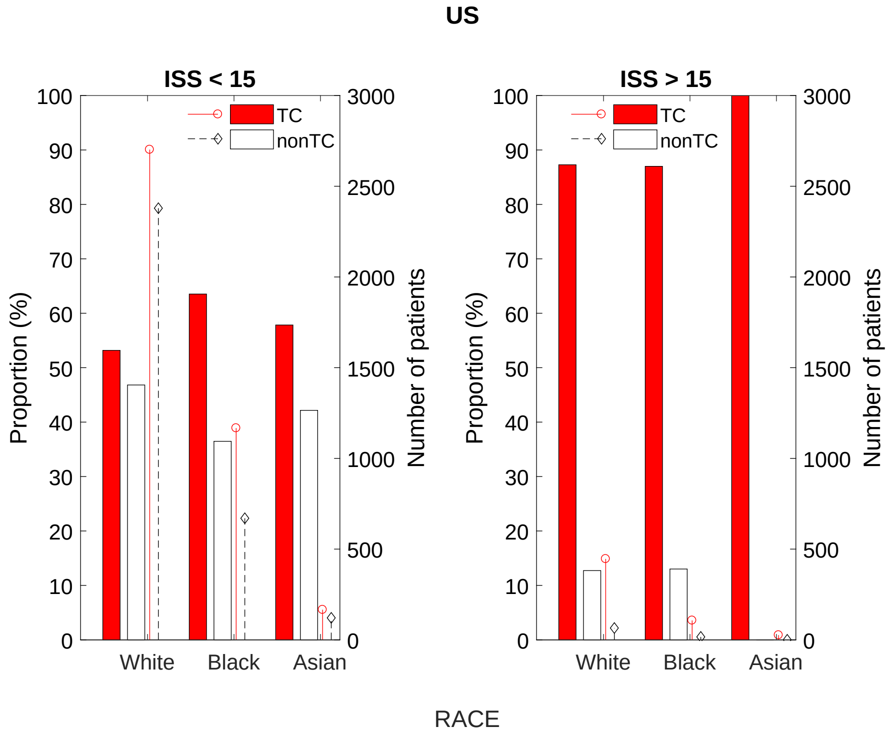

Figure 5.3: The proportion (bars, left-hand-side y -axis) and number (stems, right-hand-side y-axis) of all patients (n = 7 865) transported to a TC versus a non-TC for major and minor trauma in US according to race.

Thus, the differences between the proportion of patients sustaining minor trauma versus major trauma were statistically significant for each race, The Bonferroni-Holm correction for multiple comparisons was performed. Each race was tested against sum of all others races to investigate in which races differences were found. The results from the test were collected in Table 5.7. The differences between the proportion of patients sustaining major trauma and transported to a TC versus a non-TC for each race were not statistically significant ($p > 0.05$).

Table 5.7: Results from the Holm-Bonferroni method for finding which races are significantly different proportion for minor and major trauma of the sum of rest races in US.

Test	p-value	corrected p-value	Statistically significant if p-value < Holm-Bonferroni corrected p-value
White versus others	$4.4 * 10^{-4}$	0.0004	yes
Black versus others	$9.6 * 10^{-5}$	0.0003	yes
Asian versus others	0.9559	0.9559	no

5.2 Sweden

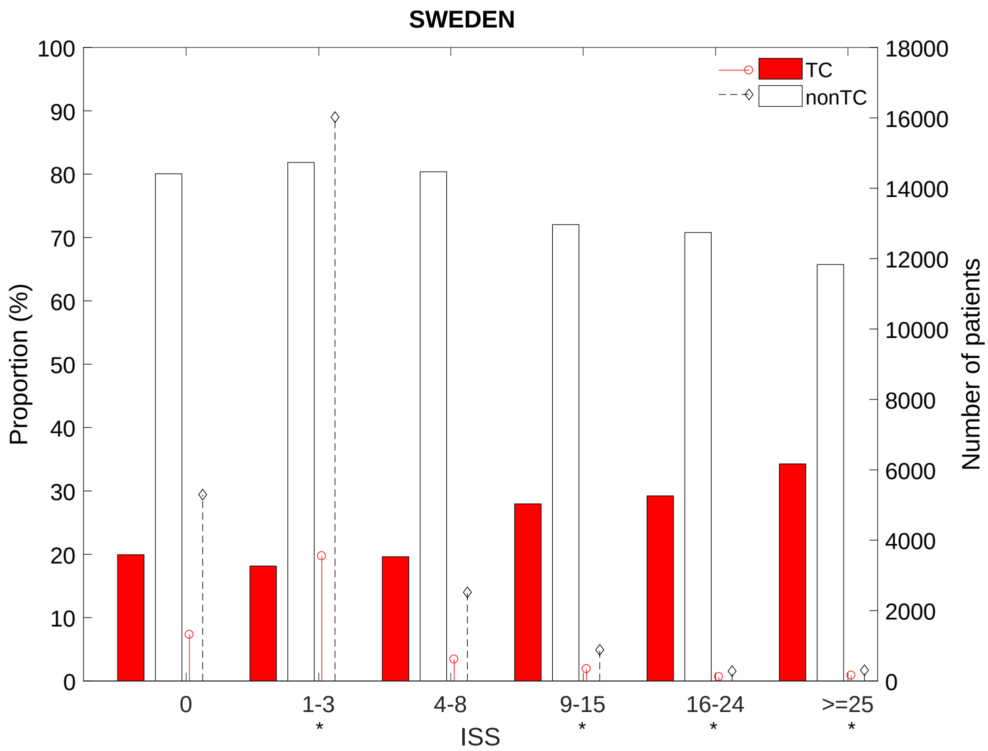

Figure 5.4: The proportion (bars, left-hand-side y -axis) and number (stems, right-hand-side y-axis) of all patients (n = 31 415) transported to a TC versus a non-TC for different ISS groups in Sweden. The asterisks indicate that the proportion of patients transported to a TC versus a non-TC differs with statistical significance for each ISS group ($p < 0.05$).

Table 5.8: The proportion and number of all patients (n = 31 415) transported to a TC versus a non-TC for different ISS groups in Sweden.

ISS	Number of patients		Proportion [%]	Chi-square	*p*-value
	TC	non-TC	TC		
0	1 319	5 296	19.9		
1-3	3 352	16 020	18.1		
4-8	615	2 519	19.6	168.85	<0.00001
9-15	344	886	28.0		
16-24	116	281	29.2		
>25	160	307	34.3		

5.3 The chi-square test for each ISS group for US and Sweden

Thus, from the chi-square test for differences between the proportion of patients transported to a TC versus a non-TC for each ISS group was statistically significant ($p < 0.05$), the Bonferroni-Holm correction for multiple comparisons was performed. Six pairwise comparisons were made to find which ISS groups are a significantly different proportion of the total in each type of medical facility (a TC versus a non-TC). Each ISS group was tested against the sum of all others (Table 5.9, 5.10).

Table 5.9: Results from the statistical tests for finding differences between the proportion of patients transported to a TC versus a non-TC for each ISS group in US.

Test	p-value	Statistically significant if p-value < Holm-Bonferroni corrected p-value
ISS 0 versus others	$9.2 * 10^{-12}$	yes
ISS 1-3 versus others	<0.00001	yes
ISS 4-8 versus others	$1.2 * 10^{-13}$	yes
ISS 9-15 versus others	<0.00001	yes
ISS 16-24 versus others	<0.00001	yes
ISS >15 versus others	<0.00001	yes

Table 5.10: Results from the statistical tests for finding differences between the proportion of patients transported to a TC versus a non-TC for each ISS group in Sweden.

Test	p-value	Statistically significant if p-value < Holm-Bonferroni corrected p-value
ISS 0 versus others	0.2446	no
ISS 1-3 versus others	$1.2 * 10^{-13}$	yes
ISS 4-8 versus others	0.7805	no
ISS 9-15 versus others	$1.2 * 10^{-14}$	yes
ISS 16-24 versus others	$7.2 * 10^{-7}$	yes
ISS >15 versus others	$3.3 * 10^{-16}$	yes

5.4 The comparision between US and Sweden

Table 5.11: The proportion and number of all patients (n = 10 280 in US and n = 31 415 in Sweden) transported to a TC versus a non-TC for major and minor trauma according to sex, age and location of road crash.

SEX	Country	Patients with minor trauma			Patients with major trauma		
		Number of patients [No.]		Proportion [Pct.]	Number of patients [No.]		Proportion [Pct.]
		TC	non-TC	TC	TC	non-TC	TC
Male	US	2 524	1 744	59.1	386	55	87.5
	SE	3 278	13 507	19.5	197	410	32.5
Female	US	2 753	2 452	52.9	321	45	87.0
	SE	2 552	11 214	18.5	79	178	30.7
AGE	Country	Patients with minor trauma			Patients with major trauma		
		Number of patients [No.]		Proportion [Pct.]	Number of patients [No.]		Proportion [Pct.]
		TC	non-TC	TC	TC	non-TC	TC
18-55	US	4 140	3 080	57.3	520	60	89.7
	SE	4 756	19 325	19.8	178	353	33.5
>55	US	1 113	1 110	50.1	186	40	82.3
	SE	1 074	5 396	16.6	98	235	29.4
LOCATION	Country	Patients with minor trauma			Patients with major trauma		
		Number of patients [No.]		Proportion [Pct.]	Number of patients [No.]		Proportion [Pct.]
		TC	non-TC	TC	TC	non-TC	TC
Rural	US	1 166	1 943	37.5	177	64	73.4
	SE	3 984	16 116	19.8	215	457	32.0
Urban	US	4 115	2 258	64.6	530	36	93.6
	SE	1 547	6 899	18.3	38	96	28.4

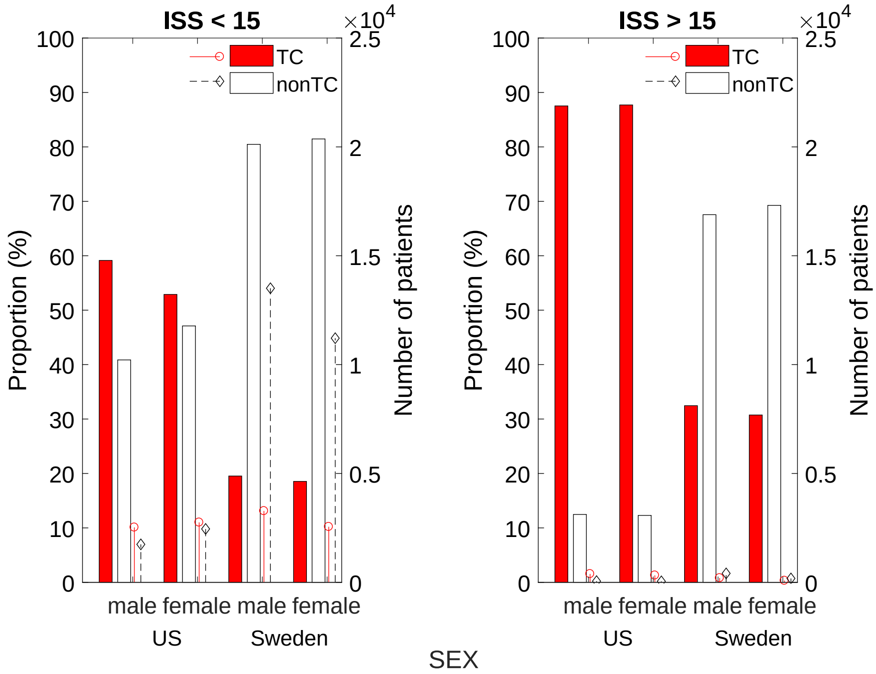

Figure 5.5: The proportion (bars, left-hand-side y -axis) and number (stems, right-hand-side y-axis) of all patients (n = 10 280 in US and n = 31 415 in Sweden) transported to a TC versus a non-TC for major and minor trauma according to sex.

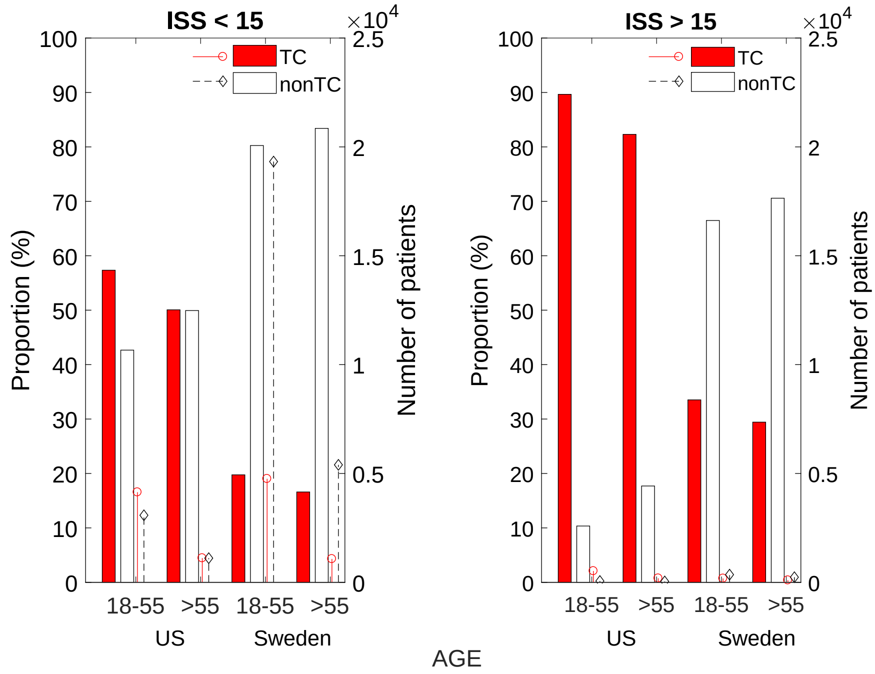

Figure 5.6: The proportion (bars, left-hand-side y -axis) and number (stems, right-hand-side y-axis) of all patients (n = 10 249 in US and n = 31 415 in Sweden) transported to a TC versus a non-TC for major and minor trauma according to age.

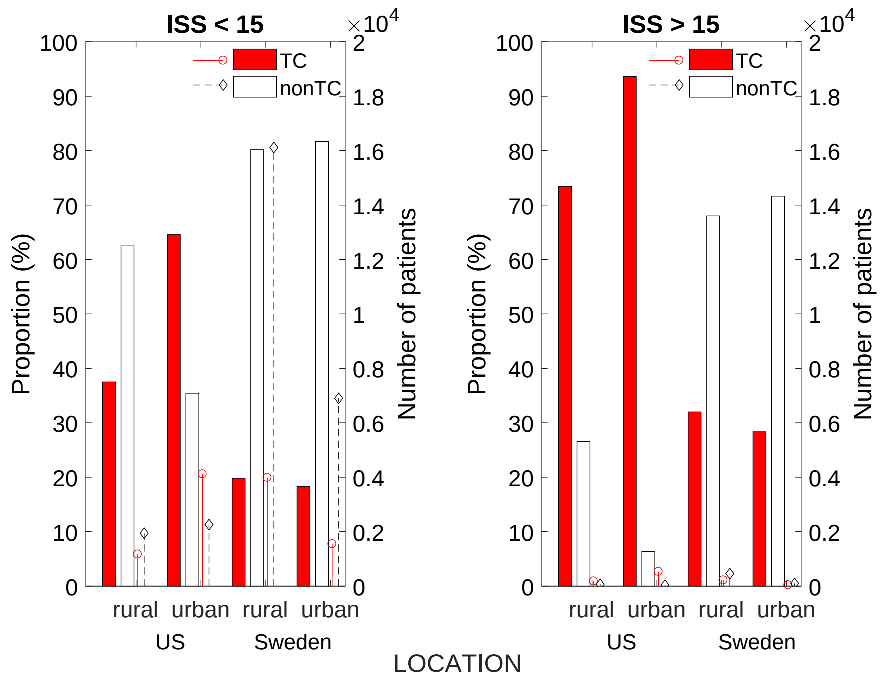

Figure 5.7: The proportion (bars, left-hand-side y -axis) and number (stems, right-hand-side y-axis) of all patients (n = 10 289 in US and n = 29 352 in Sweden) transported to a TC versus a non-TC for major and minor trauma according to location of road crash.

6
Discussion

In this study, the analysis of prehospital transportation decision for patients sustaining major trauma in RTC in US and Sweden was conducted. This study is based on data obtained from the *Swedish TRaffic Accident Data Acquisition* (STRADA) database and from the *National Automotive Sampling System - Crashworthiness Data System* (NASS-CDS). In both cases data from RTC occurred from 2010 to 2015 were analysed.

In US, the proportion of patients with ISS 0 and ISS 1-3 transported to TC and non-TC is similar (49.9% patients transported to TC for ISS 0; 50.2% patients transported to TC for ISS 1-3). However, the significant difference between the proportion of patients transported to TC versus non-TC exists for each ISS group compared to the proportion of all others ISS group (Table 5.9). Patients with ISS above 4 are more frequently transported to TC than non-TC (ISS 4-8, 9-15, 16-24, >25, proportion of patients transported to TC 67.3%, 80.3%, 88.2%, 86.9%, respectively). Especially, patients sustaining major trauma (ISS $>$ 15) are more often transported to TC than to non-TC. Observed results indicate overtriage which may be caused by the field triage protocol.

In Sweden, the proportion of patients transported to non-TC compared to TC is significantly higher for each ISS group. Along with the higher ISS, from the ISS 4-8, the proportion of patients transported to TC increases (ISS 4-8, 9-15, 16-24, >25, the proportion of patients transported to TC 19.6%, 28.0%, 29.2%, 34.3%, respectively). Nevertheless, significant differences between the proportion of patients transported to TC versus non-TC were not found for ISS 0 (TC 19.9%) and ISS 4-8 (TC 19.6%) compared to the proportion of all others ISS group (Table 5.10). Observed results indicate many RTC patients with severe injuries are transported to a hospital with a lower level of care. This may be caused by undertriage or by a lack of formal designated trauma care system and major trauma destination policies in Sweden.

In similar study conducted by Candefjord et al. [50], authors analysed data extracted from STRADA database from 2007 to 2014. The proportion of patients sustaining major trauma and transported to TC was 31.9% (276 out of 864 major trauma patients) for years 2010-2015, compared to 38.0% (1 288 out of 3 411 major trauma patients) for years 2007-2014. The proportion of patients aged >55 years sustaining major trauma and transported to TC is accounted for 33.5% for years 2007-2014 and 35.5% for years 2010-2015. The proportion of males sustaining major trauma and transported to TC is accounted for 71.9% for years 2007-2014 and 71.4% for years 2010-2015. The proportion of patients involved in road crash in an urban environment sustaining major trauma and transported to TC is accounted for 46.6%

for years 2007-2014 and 15.0% for years 2010-2015. The difference in the proportion of patients involved in road crash in an urban environment sustaining major trauma and transported to TC is significant between years 2007-2014 and 2010-2015. The possible reason for obtaining such a difference may be that crashes occurred in rural areas between years 2010-2015 were preferred to register. The another reason can be also changes in the prehospital organisations. In 2005, regulation entered into force that at least one Registered Nurse (RN) should mann the ambulance. Presence of the RN as a part of the prehospital emergency care has been improved the treatment. RNs were allowed to administer different medicines to alleviate patient's suffering, that emergency medical technicians were not allowed to give any medications. This change led to development of possibilities to transport patients to an optimal level of care rather that transport all patients to the TCs.

Injured patients in RTC were 761.3 in US and 149.7 in Sweden per population 100 000 in 2015 (Table 3.1). As can been seen a difference between these countries is huge. More amount of injured patients in US result in the need of a well organized trauma care system. As it is marked in a guideline to create and categorize trauma centers published by *American College of Surgeons Committee on Trauma* (ACS-COT), different levels of TC need a specified volume of injured patients.

It should be emphasized that in US, in each analysed situation, the number of patients transported to TC is higher compared to the number of patients transported to non-TC. The opposite situation is in Sweden, where the most patients are transported to non-TC regardless of age, sex, race or BMI. It should be also highlighted that in both countries, a higher number of patients sustain minor trauma than major trauma.

The proportion of patients aged >55 years sustaining major trauma (US 28%, Sweden 38.5%) are significantly higher than the proportion of patients aged >55 years sustaining minor trauma (US 23.5%, Sweden 21.2%) in both countries (Table 5.1). Moreover, the proportion of patients aged >55 years sustaining major trauma and transported to TC is significantly lower than the proportion of patients aged >55 years sustaining major trauma and transported to non-TC in US. It is noticed that younger patients (<=55) are more likely transported to TC than older patients (>55) in US, which is also presented in the Figure 5.6. However, according to the field triage guideline, elderly people have greater chances to transport to a TC than younger patients. Thus, the reason of transported more number of younger patients than elderly patients to TC may be a human factor. The difference between age of patients and major TC versus major non-TC are not significant in Sweden (Table 5.1).

The statistically significant difference exists between the proportion of gender and the proportion of severity of injury (minor versus major). The higher proportion of sustaining major trauma are men (54.6% of men), while the higher proportion of sustaining minor trauma are women (45.1% of men) (Table 5.1 and Figure 5.5). In the US as well in Sweden, there does not exist a statistically significant difference between gender and type of transportation to TC and non-TC of patients sustaining major trauma (Table 5.1 and Figure 5.5). However, in Sweden, there is a higher proportion of males than females in the sample (55.4% of males), the difference between the proportion of patients' gender is even much higher for major trauma (TC 70.3% of males and non-TC 71.4% of males).

The proportion of patients sustaining minor and major trauma injured in a road crash in an urban environment is significantly higher in US compared to Sweden. If comparing the proportion of patients sustaining major trauma and transported to TC versus non-TC, again, the proportion of patients from the crashes occurred in an urban environment are higher in US than in Sweden. Especially, the proportion of patients transported to TC, where 75% crashes occurred in an urban location in US compare to only 15% crashes occurred in an urban location in Sweden.

According to BMI, any significant differences was found between the proportion of patients sustaining minor versus major trauma for each BMI level and between the proportion of patients sustaining major trauma and transported to TC versus non-TC for each BMI level. Nevertheless, the analysed sample accounted for almost two times more (1.94) overweight and obese patients than patients with normal BMI (Table 5.3).

In US, the proportion of patients sustaining minor versus major trauma are significantly different for each race (Table 5.6). The highest proportion of major trauma patients is observed for a white race (9.1% of major trauma) and the lowest for a black race (6.3% of major trauma). After the Holm-Bonferroni correction, the proportion of Asian patients is not significantly different from sum of all other patients (Table 5.7). It is worth to notice that the sample of Asian patients accounted for 313, which is relatively small compared to a white race (5 592) and a black race (1 960). In the analysed sample, there were not any Asian patients transported to non-TC. Moreover, the proportion of patients sustaining major trauma and transported to TC versus non-TC for each race are not significantly different (Table 5.5).

There were several limitations in the thesis. The conducted analysis was dependent of completeness of databases from NASS-CDS and STRADA. Not every desirable variable was available in the both databases. Therefore, the analyses of severity and type of transportation for BMI levels and different races were not performed for Swedish data, because of lack of the accessibility for these variables. A primary plan included injured body region analyses. However, the severity for specific body regions were not included in our US database. The comparison between severity of body region injuries in US and Sweden could be an extension of the analysis done in this work for the future plan. The analysis and the comparison of road crash data between countries can contribute to establish and improve road safety policies in own country.

7 Conclusion

The field triage protocols should be highly considered for prehospital setting to provide a proper care for patients. The failure to develop field triage protocols may lead to overtriage or undertriage. The field triage protocols should be support for Emergency Medical Service to make a decision where patient should be transported.

The conducted study indicates that in Sweden many RTCs patients with severe injuries are transported to hospitals with a lower level of care. This may be caused by undertriage but there are other possible reasons. It is important to emphasise that result does not indicate inferior medical care in Sweden. TCs in Sweden were designated by the researches according to a guideline, because there is lack of formal designated trauma care system and major trauma destination policies. Thus that, we can not completely compare those formally designated TCs in US to those TCs in Sweden. Introduction of trauma destination policies in Sweden may help in the future to perform more detailed comparisons between those countries with formally designated TCs. To maintain high competence among Emergency Medical Service and medical equipment large enough number of patients is required. Sweden is consider one of the top scoring country with the road safety.

Therefore, the number of RTCs patients is much lower than in US. In US, observed results indicate low undertriage but at the price of high overtriage, which may be linked to the field triage protocol where it is stated that "*When in doubt, transport to a trauma center*". If overtriage occurs, the hospital staff may be not properly focused on more severely injured patients because of too high number of treated patients at the time. In the situations where are numerous victims, overtriage has been reported to correlate with increased mortality for patients sustaining major trauma.

The time is crucial in potentially life-saving decision. Transport of patient to the right hospital faster may maximise chance of making a successful recovery. TCs are designed to provide patients access to specialists continuously and to care severely injured patients immediately.

This study offers a unique insight into the rate of prehospital transportation decisions for patients sustaining major trauma and points out the differences between US and Sweden. Formally designated trauma care in US may contribute to establish major trauma destination policies in Sweden. Trauma care system should be identified and formally organized so severely injured patients can be provided the high-quality of care.

The analysis of patients mortality and type of transportation can be the future work to develop trauma care research. Such analysis would allow to recognise the effects of the low proportion of patients suffering major trauma and transported to TCs in Sweden.

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