Trauma - Diagnostics and Triage

FREDRIK LINDER
Trauma is a leading cause of death worldwide and it reduces years of productive life and leads to disability. Effective trauma care relies on triage, which aims to ration the use of finite resources to patients with the greatest needs. Imaging is essential in the severely injured patient, but comes at a cost of radiation exposure, which could cause cancer in up to 1/1000 patients examined with whole body computed tomography.

Paper I showed that routine whole-body CT of high-energy trauma patients may lead to excessive radiation exposure without clinical benefit. There were no missed injuries in the low risk group and the mean injury severity score (ISS) was 0.84 in this group (standard deviation SD 1.57). Paper II surveyed radiologists at 93 Nordic and 10 non-Nordic hospitals with 23 questions on usage of whole body CT in trauma. The response rate was 62% and there were several differences in criteria, protocols and radiation dose. Most, 89% consider there is a need for national/international guidelines. Paper III evaluated compliance with trauma alert criteria with the aim to describe how resources may be optimized with sustained low undertriage.

Compliance with full trauma alert and no trauma alert was 80% and 79% respectively. Compliance with limited trauma alert was only 54%, and prehospital immobilization was an independent risk factor for mistriage with an odds ratio of 1.78 (95% CI 1.42 - 2.23). Paper IV demonstrated that the newly implemented Swedish trauma team activation (TTA) criteria result in a reduction in limited TTA frequency, indicating an increased efficiency in use of resources. The over- and undertriage is unchanged compared to former criteria, thus upholding patient safety.

In conclusion, whole body CT in trauma should be used only in patients with clinical findings. The routines for use of whole body CT in trauma differ between institutions, and efforts to establish common guidelines are requested. Better compliance with alert criteria may optimize resource allocation, and the newly implemented national TTA criteria in Sweden are safe and resource efficient.

Keywords: wounds and injuries, trauma, triage, whole body computed tomography in trauma, compliance, radiation exposure, CT, radiation safety

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To Louise, Ella, Agnes and Gunnar
List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I

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II


III


IV

*Manuscript.*

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## Abbreviations

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<th>Description</th>
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<tr>
<td>AAAM</td>
<td>Association for Advancement of Automotive Medicine</td>
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<tr>
<td>ACS-CoT</td>
<td>American College of Surgeons Committee on Trauma</td>
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<td>AIS</td>
<td>Abbreviated Injury Score</td>
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<tr>
<td>ALARA-principle</td>
<td>As Low As Reasonably Achievable principle</td>
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<tr>
<td>ATLS</td>
<td>Advanced Trauma Life Support</td>
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<tr>
<td>CT</td>
<td>Computed Tomography</td>
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<tr>
<td>DLP</td>
<td>Dose Length Product</td>
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<tr>
<td>ED</td>
<td>Emergency Department</td>
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<td>FAST</td>
<td>Focused Assessment with Sonography in Trauma</td>
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<tr>
<td>FFP</td>
<td>Fresh Frozen Plasma</td>
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<tr>
<td>GSW</td>
<td>Gunshot Wound</td>
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<tr>
<td>ICU</td>
<td>Intensive Care Unit</td>
</tr>
<tr>
<td>ISS</td>
<td>Injury Severity Score</td>
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<tr>
<td>MOI</td>
<td>Mechanism of Injury</td>
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<tr>
<td>MTP</td>
<td>Massive Transfusion Protocols</td>
</tr>
<tr>
<td>MVC</td>
<td>Motor Vehicle Crash</td>
</tr>
<tr>
<td>NISS</td>
<td>New Injury Severity Score</td>
</tr>
<tr>
<td>PRBC</td>
<td>Packed Red Blood Cells</td>
</tr>
<tr>
<td>SIR</td>
<td>Swedish Intensive-care Registry</td>
</tr>
<tr>
<td>SOP</td>
<td>Standard Operating Procedures</td>
</tr>
<tr>
<td>STRADA</td>
<td>Swedish Traffic Accident Data Acquisition</td>
</tr>
<tr>
<td>SweTrau</td>
<td>Swedish trauma registry</td>
</tr>
<tr>
<td>TTA</td>
<td>Trauma Team Activation</td>
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<tr>
<td>WBCT</td>
<td>Whole Body Computed Tomography</td>
</tr>
<tr>
<td>WWI</td>
<td>World War I</td>
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<tr>
<td>WWII</td>
<td>World War II</td>
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Introduction

Trauma is a leading cause of death in Sweden for young adults between 15-44 years\(^1\). Worldwide, trauma is a health problem with great magnitude that shortens life expectancy as well as productive life and leads to disability. The financial costs are high and it has been estimated that 25\% of all emergency department (ED) visits is Sweden are due to trauma and these patients consume almost 1,000,000 days of hospitalization every year. A leading cause of trauma is motor vehicle crashes (MVC) with 1.25 million yearly deaths worldwide. About 90\% of these fatalities occur in low- and middle-income countries even though these countries have only half of the world’s vehicles\(^2\). The changes in the number of road traffic deaths by income status shows that low-income countries have an ever-increasing death toll and high-income countries have a decreasing death toll.

Despite the recent decrease of MVC in high-income countries such as Sweden, other mechanisms of injury (MOI) are more constant in prevalence and result in morbidity, disability, mortality and major costs.

To meet this challenge, the development of a comprehensive trauma organization has been the focus of trauma care over the last decades. This includes effective and competent pre-hospital life support. Structured transport algorithms in place where hospitals are bypassed in order to deliver highly specialized trauma care at trauma centers with a high concentration of medical resources. At the trauma centers care is often provided using the ATLS\(^\circ\) system and guidelines, and data is reported to registries following the Utstein style data recommendations\(^3\), such as the Swedish trauma registry (SweTrau), for research- and developmental purposes. Effective trauma care relies on triage, which aims to ration the use of fine resources to patients with the greatest needs, prompt diagnosis of life threatening pathologies with clinical examination and imaging, and diligent delivery of surgical care when needed.

History

Dominique Jean Larrey (1766-1842) has been described as the father of triage and modern military surgery. He developed a plan for rapid evacuation of wounded soldiers from the battlefield using *ambulances volantes* (“flying ambulances”). These carriages with two horses were the pioneers to ambulances of today and provided transport to care for all combatants, regardless of rank
or nationality. Larrey’s sanitary system, surgical mastery and dedication are even considered a key factor in the success of Napoleon Bonaparte’s campaigns and battles. Before the introduction of the *ambulances volantes* the wounded were left in field until the engagement was over, and if they were not captured or killed by enemy soldiers, the delay of 24-36 hours rendered casualties for conditions that would be salvageable if treated urgently.

The system of rapid evacuation during battle to medical care boosted morale among soldiers and was also a part of an early triage protocol where the medical needs of the patient had priority. Larrey established triage rules that were over a century before it’s time:

…those dangerously wounded must be attended first entirely without regard to rank or distinction and those less severely wounded must wait until the gravely hurt have been operated and addressed. The slightly wounded can go to the hospital in the first and second line, especially officers, because the officers have horses.

Dominique Jean Larrey was truly a great trauma surgeon and even with his many contributions to surgical care including wound management, limb amputation, effective control of hemorrhage, drainage of hemothorax and packing of sucking chest wounds, Napoleon Bonaparte expressed his amazement of the results of Larrey’s sanitary system with the words:

Your work is one of the greatest conceptions of our age and alone is sufficient to ensure your reputation.

**Wartime experience**

**World War I**

A major leap in the advances of surgery was made during World War I (WWI). The development of surgery at the front with motorized ambulance services and the implementation of x-rays as a diagnostic tool improved the outcomes. Triage was implemented in the trenches and at casualty clearing stations located only a few kilometers from the enemy line. The overwhelming number of injured soldiers and their needs contributed to improve surgical care in a time of despair and insufficiency. Operations performed at a single casualty clearing station during a few months’ time with heavy fighting is compiled in table 1.
Table 1. Operations performed at a casualty clearing station

<table>
<thead>
<tr>
<th>Ligature of arteries:</th>
<th>Amputations:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotid 5</td>
<td>Shoulder joint 14</td>
</tr>
<tr>
<td>Vertebral 2</td>
<td>Upper arm 77</td>
</tr>
<tr>
<td>Subclavian 2</td>
<td>Forearm 31</td>
</tr>
<tr>
<td>Axillary 15</td>
<td>Thigh 186</td>
</tr>
<tr>
<td>Brachial 39</td>
<td>Knee 10</td>
</tr>
<tr>
<td>Radial 18</td>
<td>Leg 76</td>
</tr>
<tr>
<td>Ulnar 8</td>
<td>Ankle 6</td>
</tr>
<tr>
<td>Ext. iliac 2</td>
<td>Various 31</td>
</tr>
<tr>
<td>Femoral 51</td>
<td>431</td>
</tr>
<tr>
<td>Popliteal 31</td>
<td>277</td>
</tr>
<tr>
<td>Ant. tibial 16</td>
<td>For drainage of pleura 49</td>
</tr>
<tr>
<td>Post. tibial 58</td>
<td>For wounds of the abdomen 106</td>
</tr>
<tr>
<td>Various 30</td>
<td>Removal of testis 33</td>
</tr>
<tr>
<td></td>
<td>277</td>
</tr>
<tr>
<td></td>
<td>For ruptured urethra 9</td>
</tr>
</tbody>
</table>

For treatment of fractures:

| Skull 189           | Plastic operations 33 |
| Vertebræ 18         | Tracheostomy 17       |
| Humerus 298         | 280                   |
| Forearm 133         | Excision and cleansing of wounds: |
| Femur 299           | Head and neck 95      |
| Leg 309             | Trunk 309             |
| Jaws 38             | Upper limb 249        |
| Various 119         | Lower limb 765        |
|                     | 1403                  |
|                     | Multiple 398          |
|                     | 1816                  |

For treatment of joints:

| Knee 183            | For conditions not due to gunshot wounds: |
| Other joints 64     | Appendicitis 34 |
|                     | Strangulated hernia 1 |
|                     | Cellulitis 53       |
|                     | Various 13          |
|                     | 101                  |

In total 4,554 surgical operations at a casualty clearing station. Total number of wounded admitted: 20,589.

Even with the improvements in transporting the patients from the battlefield to the primary surgical facilities, a consecutive series of abdominal wounds show the time of evacuation to casualty clearing station was inadequate. Only 24 out of 200 patients reached the clearing station within 3 hours, and 66 did not reach it within 12 hours. The treatment for abdominal gunshot wounds (GSW) went from conservative, with a mortality rate of 70-80%, to an active approach with laparotomy for all GSW and an outcome of about 50% mortality. Thus, surgical care with early laparotomy seemed to improve outcome and decrease mortality by 15-20%.

The practice is now to operate on all cases unless there is some reason to the contrary, and to operate on principle rather than on the indications by symptoms.
Still, the outcome seemed to be related to the time from injury to the operating theatre, with a worsening of outcome if operation was undertaken later than 12 hours after injury. An operating theatre at a casualty clearing station is shown in figure 1.

Vascular repair was seldom undertaken mainly due to retraction of blood vessels and substance deficit that made primary suture impossible.

Figure 1. Operating theatre at casualty clearing station where one senior surgeon could oversee three junior surgeons and triage the needs of the patients.

World War II

Advances in trauma care were once again accelerated as the world fell into the global conflicts of World War II (WWII). The works of DeBakey and Simeone with an analysis of 2,471 arterial injuries described the advances in trauma and vascular surgery. Bernheim, who went to many fronts of war with his own elaborate equipment for surgical use, concluded that even with the advances made in vascular repair with synthetic grafts, vein grafts or direct suture, the lack of supportive tissue and the time required to do an arterial repair made reconstructive vascular surgery unjustifiable. He remarked:

Only a foolhardy man would have essayed suture of arterial or venous trunks in the presence of infections such as were the rule in almost all the injured. 9
In total, out of 2,471 cases, only 81 suture repairs were performed and the method of choice was ligation with 1,639 cases. The amputation frequency was about 50%. Patients treated with primary repair were highly selected, but it was showed that amputation rates decreased to about 30% with primary repair.\textsuperscript{10}

The Vietnam War

In the Vietnam War the tables had turned. During the World Wars, ligation was the method of choice for vascular injury. Amputation rates were about 50%, and patients treated with direct repair or venous graft were few.

Dr Norman Rich initiated the Vietnam vascular registry, and in an analysis of 1000 cases only 15 were treated with ligation. 45.9% were treated with autogenous vein graft and 37.7% with primary end-to-end anastomosis. The amputation rate was 12.8%.\textsuperscript{11}

Background

Implementation of Advanced trauma life support (ATLS\textsuperscript{®})

The advanced trauma life support (ATLS) concept was originally developed in Nebraska, USA, in 1978.\textsuperscript{12} It followed after the tragic plane crash in 1976 where Dr Jim Styner, an orthopedic surgeon, was seriously injured along with three of his children. One child suffered minor injuries, and his wife was instantly killed. After inadequate care by today’s standards, he said:

> 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.

After 2 years of local courses the American college of surgeons committee on trauma (ACS-CoT) introduced an updated version in the USA and other countries. In 1986 several countries in South America joined in, and the course was given for the first time in Sweden in 1996. It has now been taught to over 1 million doctors in more than 50 countries, and has become a key component in care for traumatically injured patients. It is a language in trauma care, using a multi-disciplinary and evidence based approach.\textsuperscript{13}

The ATLS program is one way to provide for the trauma patient and to manage injuries. It teaches the basic skills necessary to:

1. Assess the patient’s condition, both accurately and rapidly
2. Prioritize, Resuscitate and Stabilize
3. Decide which patients need to be transferred
4. Arrange transports according to who, what, when, and how
5. Make sure optimum care is provided, and that it does not deteriorate any time during the primary and secondary survey.\textsuperscript{13}

Transfusion protocols
In the beginning of the 20\textsuperscript{th} century transfusions to restore blood volume was sometimes given intravenously with saline. More often rectally and the method of choice was per oral administration\textsuperscript{8}. In the 1920’s transfusion of whole blood was used alongside volume replacement with saline, and this practice continued until the decades after WWII when whole blood fractionation techniques opened up for more targeted transfusions while limiting the risks for transfusion reaction and infections.\textsuperscript{14}

Component therapy has become the standard of care from the 1970’s, and on. Studies on effects of component therapy compared to whole blood transfusions have been performed\textsuperscript{15}, but not on trauma patients with needs of massive transfusion.

After the second Gulf War military use of whole blood had indicated less coagulopathy in severely injured patients and in a civilian practice the use of fresh frozen plasma (FFP) and its ratio to packed red blood cells (PRBC) was studied with findings that the FFP:PRBC ratio close to 1:1 in the patient requiring massive transfusion had a survival advantage.\textsuperscript{16}

The development of massive transfusion protocols (MTP) has not only ensured the correct ratios on blood components, but also put the light on hypothermia and its role in coagulopathy, the availability of blood components, the use of fibrinogen, and the need for rapid surgical intervention to stop the bleeding.

Damage control surgery
The damage control concept originates from naval history, where the captain would set the damaged ship on ground in order to prevent it from sinking. This was used during the attacks on Pearl Harbor in 1941 with success. The stranded ships could be repaired and reused.

In 1983 H. Harlan Stone described a case series of 31 patients with onset of major coagulopathy during laparotomy\textsuperscript{17}. The first 14 patients were managed with standard hematologic replacements during laparotomy and only one patient survived. The following 17 patients had their laparotomy terminated as quickly as possible, without restoration of GI continuity, and with packing of the abdominal cavity. 11 patients in this group deemed to have lethal coagulopathy survived.
In 1993, the concept of “Damage control” surgery was introduced by MF Rotondo and CW Schwab in their landmark paper “Damage control: an approach for improved survival in exsanguinating penetrating abdominal injury.” They described the concept in a surgical context:

A deliberate and preemptive set of non-traditional resuscitative and surgical maneuvers to reverse the pre-terminal effects of exsanguinations, massive injury or septic shock. The priority of DC is to save life.

The prior works of H. Harlan Stone, articles on abdominal packing for liver hemorrhage, and the works of WWI surgeons such as Bernheim, Makins and Captain Hay in a way all described the concepts of damage control surgery. Ligate vessels instead of spending time on repair with continuous blood loss. But MF Rotondo and CW Schwab re-launched the concept in a civilian context where they showed that the most injured patients could benefit from it.

Today, Damage control surgery is part of every trauma surgeon’s toolbox to deal with the exsanguinating patient.

![Image](image.png)

*Figure 2. Second look, 48 hours after damage control laparotomy in a previously exsanguinating trauma patient.*

**Radiology**

The use of plain radiographs to map foreign bodies in penetrating trauma was introduced during the Abyssinian War of 1896 and was widespread during
It was of great help in deciding operative approach and approximating fractures. It was later further developed by the introduction of intravenous contrast medium to depict blood vessels and per-oral barium contrast media to follow the contingency of the gastrointestinal tract.

The introduction of ultrasonic Doppler devices enhanced diagnostics on vascular injuries and the introduction of ultrasonography to diagnose free fluids intra-abdominally was later adapted for trauma care in the use of ultrasonography in the focused assessment with sonography in trauma (FAST).

The major radiological breakthrough in trauma care and diagnostics for trauma is the widespread use of Computed Tomography (CT). If only one achievement in refining trauma care was mentioned, CT is at the top of the list. The Austrian mathematician Johann Radon invented the theory behind computed tomographic reconstruction in his mathematic construction that he called the Radon Transform. Sir Godfrey Hounsfield constructed the first commercial CT-scanner, and it was installed and used at Atkinson Morley hospital, London, in 1972. It took about 2½ hours to process the images by computer and the resolution was 80x80 pixels. Hounsfield and Cormack shared the 1979 Nobel prize in medicine for their inventions.

Figure 3. Sir Godfrey Hounsfield’s sketch of the principles of a computed tomography.
Use of CT in trauma care

The CT-scanners performance improved during the 80’s, and in the early 90’s CT-scans of the head, neck, thorax and abdomen were implemented in the treatment algorithms for multi-trauma patients if they were hemodynamically stable. Sweden was an early adopter of this concept, and this routine was followed by the aim to standardize CT examinations for multi-trauma patients. Most institutions implement the algorithm of a topogram followed by a native head and neck scan, intravenous contrast injection and the thorax, abdomen and pelvis scan in venous phase. Another topogram is done after 5 minutes in excretion phase. Some institutions also include a scan of the thorax; abdomen and pelvis in arterial phase or use a mixed bolus technique. The exposition to ionizing radiation is a factor to consider especially in the young patient examined with whole body computed tomography in trauma (WBCT), and over time the use of WBCT in trauma is increasing. The role of CT in trauma has developed over the last decades, and most studies have found it valuable and accurate. The use of WBCT in the multi-trauma patient reveals occult injuries when compared to selective CT-scans, but the clinical benefit is topic for discussion. The effect of WBCT during trauma resuscitation was found beneficial in a retrospective, multicenter analysis. The proportion of blunt/penetrating trauma is a factor to consider because the operative needs for patient subject to penetrating trauma is higher. In the European countries, the proportion of penetrating trauma is about 10%, thus the need for urgent surgery is less predominant. Many studies derive from North America, and the injury patterns are not the same, and conclusions must therefore be drawn judiciously. Could the use of WBCT in trauma be omitted in patients without clinical findings suggesting injury? There have been some studies suggesting a clinical prediction rule to safely omit WBCT in trauma. In paper I, we aimed to study how WBCT was used in a Nordic setting in a small and large hospital, and if we could retrospectively identify patients who did not benefit from WBCT.
Figure 4. The logistics in WBCT of a trauma patient during an exercise.

Over the last decades, and even today, there is an ongoing discussion on when, where and how to perform WBCT. These issues were addressed in a survey in the Nordic countries 2014, presented in paper II.

Triage

The “Golden hour” in trauma was first introduced in 1975, as a concept in trauma care where it was hypothesized that time from injury to definitive care was a key factor to keep short in order to decrease mortality\textsuperscript{38}. D.D Trunkey suggested the trimodal death distribution in 1983 to describe the time intervals from injury to death\textsuperscript{39}. Later studies have shown that the distribution of trauma deaths occurs at a quicker rate than previously reported, because declaration of death is not done until resuscitative measures have been taken thus prolonging the time from injury to declaration of death\textsuperscript{40,41}. The severely injured patient benefits the most from rapid assessment and treatment, and patients who are not severely injured are able to withstand a prolonged time from injury to definitive treatment.

This is the basis for field triage; to identify patients with the greatest needs and prioritize them for treatment and transport\textsuperscript{42}. Transport of the severely injured patient to a trauma center improves survival compared to a non-trauma center\textsuperscript{43}.
In this thesis focus is on the use of in-hospital triage and allocation of resources within the trauma center, and much of what is valid in field-triage, also apply in a hospital setting. The principles of triage are stated in the ACS-CoT report Resources for optimal care of the injured patient. In a two-tier triage system, full trauma team activation is based on deranged physiology such as loss of airway, hypotension, tachycardia or reduced Glasgow coma scale, and/or type specific injuries such as penetrating injuries to the torso, pelvic fractures, paralysis or amputation proximal to wrist or ankle.

Limited trauma team activation is based on mechanism of injury where MVC is a major contributor. High fall injuries are the other major mechanism that activates a limited trauma team.

The presence of impaired physiology in itself, or in combination with type specific injuries is highly sensitive for serious injury defined as Injury severity score (ISS)>15. Mechanism of injury has in several studies shown increased sensitivity in correctly identifying the severely injured patient only slightly and at the same time to decrease specificity substantially.

Over- and undertriage are factors that should be monitored, and it has been suggested that an overtriage of 25-35% is acceptable in order to keep undertriage <5%.

The authors are convinced that mechanism of injury alone is an inferior predictor for serious injury. MVC in the Nordic traffic environment with safe cars and roads are seldom the cause for severe injuries. The common use of long spine-boards for immobilization decreases compliance to alert criteria.
The trauma teams

When a full trauma team activation (TTA) is initiated, the hospital mobilizes staff to gather in the emergency department and prepare for initial assessment when the patient arrives. The TTA require doctors and nurses to discontinue with their regular tasks and to go to the trauma bay in the ED as soon as possible. If a team member is unable to attend, the alert is forwarded to another employee with the specific qualifications required. The team preparations are supervised by the trauma leader, and the radiology department and operating theatres are informed their services may be needed.

The team consists of the trauma leader, surgeon on call, anesthetist, orthopedic surgeon, radiologist and six nurses including a radiology nurse and an anesthetist nurse. At a University hospital a neuro surgeon, thoracic surgeon and vascular surgeon may also be a part of the trauma team as well as several more anesthetists. It is not uncommon with 17 doctors and nurses present at a full TTA.

The limited TTA gathers a small team with two ED nurses and the surgeon on call. A consultant trauma surgeon and the radiology department are notified of the limited TTA but their presence is not mandatory. The main difference between a limited TTA and regular trauma care where no TTA has been initiated is in timely resource allocation. A TTA takes precedence over every other patient at the ED except for ongoing resuscitation.
The injury severity score

In 1974, Dr Susan Baker, an epidemiologist at the Association for Advancement of Automotive Medicine (AAAM) introduced the Injury Severity Score\textsuperscript{49,50}. The correlation between the severity of an injury and mortality was not linear but rather exponential which was shown in this groundbreaking work. The ISS is based upon the Abbreviated Injury Scale (AIS)\textsuperscript{51} published in 1971 where every injury is given a score between 1 (minor) and 6 (lethal). The AIS has been updated several times, and in this thesis we used AIS 2005, rev. 2008\textsuperscript{52}.

The ISS is calculated by compartmentalizing the human body into nine body regions: Head, Face, Neck, Thorax, Abdomen/pelvis, Spine, Upper extremities, Lower extremities and External. The injuries in every region is categorized using AIS and given a score between 1-6. Only the most severe injury in every body region is chosen and squared giving a score between 1-25. The three most severe injuries are added into the ISS resulting in a score between 0-75. If an injury is scored as 6 by the AIS it automatically results in an ISS of 75. The ISS has been used in more than 3,600 articles listed on PubMed (Boolean search phrase “injury AND severity AND score AND iss”) and remain the golden standard in injury severity scoring.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{The original figure showing the exponential increase in mortality with a more severe injury\textsuperscript{49}.}
\end{figure}
The new injury severity score

The ISS does not compensate for the fact that there can sometimes exist multiple severe injuries within the same body region. This is often the case in penetrating injuries where one body region, for instance the abdomen, can sustain severe injuries to i.e. liver, vena cava, stomach and spleen. The AIS for these injuries could be liver-3, vena cava-5, stomach-3 and spleen-4. The ISS for this patient would be 25, but the New Injury Severity Score (NISS) uses the three most severe injuries regardless of body regions and would in this case result in \(3^2 + 4^2 + 5^2 = 50\). The maximum score of NISS is 75 and it resembles ISS in all other aspects apart from the use of body regions.

The NISS was introduced in 1997 and has been used in 175 articles (Boolean search phrase “new AND injury AND severity AND score AND niss”). The accuracy in predicting mortality with the NISS has been studied in a systematic review and found to be similar to the ISS but it can be deemed inferior to ISS in blunt trauma.

Over- and undertriage

Evaluation of triage algorithms can be performed in numerous ways. The most definitive being differences in mortality. The aim of triage is correct resource allocation and the best evaluation should focus on the patient receiving adequate resources in a timely manner. There are however several pitfalls in this, the most obvious that the full extent of injuries is unknown when triage is performed. One way to evaluate triage is to study resource allocation to those patients in need of an immediate surgical procedure at primary survey. The current standard procedures in evaluating over- and undertriage is based on evaluating proportions of patients in different aspects. Patients are dichotomized depending on their injury severity score with a cut off at a score of 15 and labeled “not severely injured” or “severely injured”. This variable in then cross-tabulated to whether or not the patient initiated a full trauma team activation (TTA). The two methods used in our studies are presented below.

The Matrix method

The gold standard in triage evaluation presented in figure 7. The overtriage is calculated by the proportion of patients not seriously injured (ISS<15) initiating a full TTA. The undertriage is calculated by the proportion of severely injured patients (ISS>15) not initiating a full TTA.
### Other methods for assessment of triage

The Matrix method has an inherent error: If one reduces initiation of limited TTA, the denominator in the Matrix method undertriage calculation is reduced resulting in an increased undertriage proportion even if the actual number of severely injured patients not initiating a full TTA is unaffected or even reduced. The increase of undertriage suggest insufficient means to triage patients correctly and is a medical risk. But if the increase is based on our increasing ability to correctly divert uninjured patients away from the trauma bay the increase in undertriage is false. This has been observed at several institutions world-wide, and an alternative method for calculating undertriage was recently commented on by Peng, et. al\(^55\).

Instead of comparing the proportion of severely injured patients who did not initiate a full TTA with all patients who did not initiate a full TTA like the Matrix method, the alternate method compares the proportion of severely injured patients who did not initiate a full TTA with all severely injured patients. This results in a dichotomization of the severely injured where it is preferable to have the larger proportion initiate a full TTA, but the proportion is completely unaffected by a decrease or increase in limited TTA. This model is illustrated in figure 8.

<table>
<thead>
<tr>
<th></th>
<th>Not severely injured (ISS&lt;15)</th>
<th>Severely injured (ISS&gt;15)</th>
<th>Sum:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full TTA</td>
<td>A</td>
<td>B</td>
<td>A+B</td>
</tr>
<tr>
<td>Limited TTA</td>
<td>D</td>
<td>E</td>
<td>D+E</td>
</tr>
<tr>
<td>Sum:</td>
<td>A+D</td>
<td>B+E</td>
<td></td>
</tr>
<tr>
<td><strong>Matrix method:</strong></td>
<td>Overtriage A/(A+B)*100</td>
<td>Undertriage E/(D+E)*100</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 7. The Matrix method for calculating over- and undertriage. ISS=Injury Severity Score, TTA=Trauma Team Activation.*
National consensus based trauma team activation criteria

In 2014 the sponsor of the Swedish trauma registry (SweTrau), the Swedish trauma association, held a meeting where the inclusion- and exclusion criteria for the registry was discussed. It was decided that the inclusion criteria would be changed from only including patients with NISS>15 to also include all patients initiating a TTA. This change would not only increase the number of registered patients by a factor of ten, but also exploit a weakness in the registry: Would we compare the same patients if there was no national TTA criteria?

At first it was argued that we would be able to study registered trauma patients regardless of the differences in inclusion due to different sets of TTA criteria. With increasing evidence to support exclusion of MVC as stand-alone criteria to initiate limited TTA, however, a presentation of current evidence for every single TTA criteria and its validity was held at the Swedish Trauma Network meeting in Stockholm 2015. At this meeting, financial and administrative support was offered from a public Swedish insurance company (LÖF) to form an expert panel with the aim to present consensus-based TTA criteria.

The new national TTA criteria were presented December 1st 2016, and step-wise implemented in Sweden between December 1st 2016 and December 31st 2017. At present date, the criteria are to the best of our knowledge used at all Swedish hospitals dealing with trauma patients.

The implementation of the national consensus-based TTA criteria warranted a prospective clinical trial in order to test the accuracy, safety and validity of the new TTA criteria. In order to do so, the TRAUMALERT-study was designed as a prospective stepped wedge cohort study of the new criteria

Figure 8. The alternate method for calculating undertriage. ISS=Injury Severity Score, TTA=Trauma Team Activation.
in the Uppsala-Örebro region including five hospitals serving 1.2 million inhabitants.

We hypothesized that the new TTA criteria would decrease limited trauma team activation by 50% with sustained levels of over- and undertriage.
Aims

The overall aim of this project was to evaluate the current practices in trauma patient assessment and triage in a Nordic context, as well as to identify possibilities for further improvement in these areas. The specific aims were:

I To assess the use of WBCT in a modern trauma cohort in Sweden and evaluate if risk stratification criteria can be used for deciding need of imaging in patients subject to high-energy trauma.

II To identify Nordic trauma centers WBCT imaging protocols, radiation dose, and integration in trauma care, and to inquire about the need for common Nordic guidelines.

III To investigate if current trauma team activation criteria result in acceptable under- and overtriage according to the Matrix method, and to estimate compliance to alert guidelines.

IV To evaluate the safety and efficacy of the new national trauma team activation criteria in Sweden.
Patients and Methods

Paper I

This study assesses the use of WBCT in trauma in a retrospective two-center cohort study. All trauma patients presenting to two hospitals (a university hospital (July-December 2008), and a rural county hospital (January 2009-December 2010) were included in this study. The patients were identified from the manual trauma register kept in the ED of the two hospitals during this time-period.

Patients were retrospectively divided into 3 groups based on risk of injury on first clinical evaluation. The risk stratification between high and intermediate risk was based on the ACS-CoT guidelines for full and limited trauma team alerts:

1. High risk – Patients with signs of compromise to vital functions or predefined injury types, Figure 9.

2. Intermediate risk – Patients without signs of compromise to vital functions or predefined injury types, but with clinical findings suggesting at least one moderate injury (AIS ≥ 2), or intoxication.

3. Low risk – Patients with clinical findings limited to minor injuries (AIS ≤ 1) and no intoxication.

The included patients medical records were reviewed and information extracted regarding patient age at admission, gender, mechanism of injury, findings at clinical examination, use of radiological imaging (WBCT and/or others), findings at radiological imaging, changes in radiological reports (prelim-
inary vs final report), accidental findings, blood alcohol level, operations, intensive care, admission and follow-up. All patient records were reviewed for follow-up visits from the time of initial observation through December 2013 (a minimum of 36 months follow-up period).

Injury severity was graded using the Abbreviated Injury Score (AIS-2005 rev 08) and the AIS was used to calculate the Injury Severity Score (ISS)\textsuperscript{49}. Patients with an ISS above 15 are considered as severely injured patients.

The three groups were assessed with regards to patient age and sex, mechanism of injury, the use of WBCT, radiological findings, ISS and admission to surgical ward or intensive care unit (ICU) and mortality. Subgroup analyses were performed based on mechanism of injury, admitting hospital and on patients examined with WBCT.

**Paper II**

This study surveys the use of WBCT in trauma at Nordic trauma centers. A survey was sent to 95 Nordic hospitals and the radiologist in charge of emergency radiology or CT was asked to complete the questionnaire. The selection of hospitals was based on web-search, and hospitals with emergencies departments where name and address to trauma radiologist or head of radiology department could be found: Sweden (n=54), Denmark (n=21), Norway (n=5), and Iceland (n=2). A board member with personal knowledge of whom to contact in Finland selected 13 hospitals in Finland to include. The survey was also sent to 5 major trauma centers in the USA, two in the Netherlands, one in Belgium, one in Italy, and one in England. The questionnaire comprised 23 multiple choice and free text response questions. The questionnaire is found in the appendix of this thesis. Reminders were sent two times to the participants, and they were also offered to have the questionnaire sent by regular mail, in order to ensure maximum response frequency.

**Paper III**

This study assesses triage in a retrospective single center cohort. All trauma patients at a tertiary referral trauma center during 2012 were identified, and all primary trauma patients were included in the study.

Medical records were retrieved and 32 parameters were recorded including: age, gender, date of admission, MOI, trauma team activation, findings at physical examination, radiological examinations and results, blood-alcohol level, NISS, admission and level of care, surgeries and diagnoses according to ICD-10.
The injury severity was calculated using the AIS-2005 rev 08 and this was used to calculate the ISS and NISS\textsuperscript{53}. Over- and undertriage was calculated using the Matrix method\textsuperscript{44}.

At the study center, triage was performed by a senior nurse in the ED when contacted by the pre-hospital personnel or by a senior anesthesiologist in the medical helicopter service. Triage-criteria are shown in Figure 9.

Within the current study, compliance to current trauma alert criteria for full-, limited-, and no trauma team was calculated by studying the pre-hospital reports and re-triage the patients according to triage-criteria.

Triage was assessed with regards to age, sex, blood-alcohol level, NISS, MOI, compliance to alert-criteria, over- and undertriage and admission to surgical ward or ICU. Subgroup analyses were performed on over- and undertriage and compliance to alert criteria based on MOI.

**Paper IV**

This study assesses the safety and efficacy of new national trauma team activation criteria in a prospective step-wedged population-based cohort of trauma patients. All trauma patients registered in SweTrau at 5 hospitals in the Uppsala-Orebro region were included in this study. Four hospitals included patients 6 months prior to and after the introduction of the new TTA criteria. One hospital included patients 4.5 months prior to and after the introduction of the new criteria.

Patients were prospectively included upon initiating a TTA and registered in SweTrau. After collection of baseline data, the new TTA criteria was introduced and patients were included at an equal time before and after the intervention. Data regarding intervention group, age, gender, type of trauma team activation, mechanism of injury, injury severity according to NISS/ISS, Glasgow Coma Score, pre-injury ASA and mortality was recorded and assessed for over- and undertriage with the Matrix method and the proportion of severely injured patients (ISS>15) not initiating a full TTA compared to all severely injured patients.

Risk-factors for undertriage were assessed with binary logistic regression analyses and a sensitivity analysis was performed on one hospital with a pre-hospital TTA routine prior to the implementation of the new TTA criteria.

**Statistics**

Data were assessed for normality with histograms. Categorical data were reported as ratios with 95% confidence intervals (CI), and were assessed with chi-square when appropriate. Normally distributed continuous data were re-
ported as means with standard deviation (SD), and were compared with Student’s t-test. Non-normally distributed data were reported as medians with interquartile range (IQR) and compared with Mann-Whitney-U test. Predictors for undertriage were assessed in a multivariable binary logistic regression analysis. A p-value of <0.05 was regarded as significant. Statistical analyses were performed with IBM SPSS Statistics version 22-25 (IBM Corp, Armonk, New York, USA) and Microsoft Excel 2013 (Microsoft, Redmond, Washington, USA).

Ethical considerations

Paper I and III are based on retrospective data from a local trauma-registry, anonymous data collected at a county hospital for evaluation purposes and data collected at a university hospital for quality improvements. An application was sent to the local ethics committee with a request to use collected anonymized data for research. The committee waived the need for ethical approval, regarding previously collected data, but did not have any objections for the use of the data in research. The committee approved the acquiring of future data without informed consent, for validation purposes. (Dnr 2014–250).

In Paper IV the optimal methodology to study this intervention without bias would have been a randomized controlled study, where patients would have been triaged with one of the two criteria based on randomization. Although we initially aimed for such a study design, it was not accepted by the ethical review board (Dnr 2016-202). They required informed consent prior to randomization from all patients, which we regarded as impossible to achieve. The study design was then changed to a prospective stepped wedge cohort design with data collection in the Swedish trauma registry. The ethical review board approved the study (Dnr 2017-405).
Figure 10. Previous trauma alert criteria used in paper I, III and IV based on ACS-CoT Orange book. Mechanisms of injury (above) initiate limited trauma team, de-ranged physiology and type specific injuries initiate a full trauma team.
Nationella traumalarmskriterier

Nivå 1 – Fullt traumateam

Fysiologiska kriterier

- Behov av ventilationsstöd
- AF <10 eller >29
- Barn: Andningspåverkan
- BT <90 eller ej palpabel radialispuls
  - Barn: Kapillär återfyllnad >2 s
  - Barn: Puls
    - 0–1 år: <90 eller >190
    - 1–5 år: <70 eller >160
- RLS ≥3 eller GCS ≤13

Anatomiska kriterier

- Penetrande våld mot hals, huvud, bäl, extremiteter ovan armbåge/knä
- Öppen skallaskada/impressionsfraktur
- Ansikts-/halsskada med hotad luftväg
- Instabil/deformerad bröstkorg
- Svår smärta i bäcken/misstänkt bäckenfraktur
- Misstänkt ryggmärgsskada
- ≥2 frakturer på långa rörben
- Amputation ovan hand / fot
- Stor yttre blödning
- Brännskada ≥18 % eller inhalationsskada

Skademekanism

- Bilolycka > 50 km/h utan bilbälte
- Utkastad ur fordon
- Fastklämd med losstagningsstid >20 min
- MC-olycka (eller motsvarande) >35 km/h
  - Barn: Påköröverkör av motorfordon
- Fall >5 m
  - Barn: Fall >3 m

Observandum

Om inga kriterier för traumalarm är uppfyllda, men ett eller flera observandum föreligger, ska detta föranleda kontakt med journhavande läkare för att prioritera handläggning av patient, anpassa behov av larm eller korrigeras larmnivå.

- Successiv försämring av misstänkt allvarligt skadad patient
- Ökad blödningsrisk (antikoagulantia)
- Ålder <5 år eller >60 år
- Allvarlig grundsjukdom
- Hypothermi <35°C
- Drogpåverkad
- Gravid

Säker Traumavård 2017

Figure 11. The new national consensus-based TTA criteria evaluated in paper IV.
Results

Paper I

A total of 523 patients were included. Eight patients were excluded; 3 due to de-activation of trauma alert; 5 patients could not be identified retrospectively. Only 1.1% of all patients were subject to penetrating trauma. Patient characteristics are shown in table 2 and the ISS score of the different risk groups is presented in figure 12. This box-plot visualizes the distributions of injuries and how few patients that were seriously injured. The mechanisms of injury, and their distribution in the groups are shown in table 3.

Table 2. Patient characteristics according to risk groups

<table>
<thead>
<tr>
<th></th>
<th>Low risk group (n=139)</th>
<th>Intermediate risk group (n=322)</th>
<th>High risk group (n=62)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean, years (SD)</td>
<td>32.52 (21.35)</td>
<td>37.66 (20.24)</td>
<td>38.49 (21.13)</td>
<td>0.035</td>
</tr>
<tr>
<td>Male gender % (n):</td>
<td>61.2 (85)</td>
<td>64.3 (207)</td>
<td>77.4 (48)</td>
<td>0.075</td>
</tr>
<tr>
<td>Mechanism of injury % (n)</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Unprotected traffic victim (motorcycle, bike, pedestrian)</td>
<td>20.9 (29)</td>
<td>34.2 (110)</td>
<td>24.2 (15)</td>
<td></td>
</tr>
<tr>
<td>Protected traffic victim</td>
<td>62.6 (87)</td>
<td>36.3 (117)</td>
<td>40.3 (25)</td>
<td></td>
</tr>
<tr>
<td>Fall&lt;3m</td>
<td>10.8 (15)</td>
<td>13.4 (43)</td>
<td>3.3 (2)</td>
<td></td>
</tr>
<tr>
<td>Fall&gt;3m</td>
<td>2.9 (4)</td>
<td>7.8 (25)</td>
<td>17.8 (11)</td>
<td></td>
</tr>
<tr>
<td>Other (crush, blunt, SW)</td>
<td>2.9 (4)</td>
<td>8.4 (27)</td>
<td>14.5 (9)</td>
<td></td>
</tr>
<tr>
<td>Examined with WBCT % (n)</td>
<td>32.4 (45)</td>
<td>60.2 (194)</td>
<td>82.3 (51)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Injury on WBCT % (n)</td>
<td>0 (0)</td>
<td>44.8 (87)</td>
<td>74.5 (38)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Specific radiological exams % (n)</td>
<td>46.8 (65)</td>
<td>58.4 (188)</td>
<td>43.5 (27)</td>
<td>0.016</td>
</tr>
<tr>
<td>Injury Severity Score, mean (SD)</td>
<td>0.84 (1.57)</td>
<td>4.42 (6.30)</td>
<td>16.48 (18.14)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>S-ethanol in mmol/l in intoxicated patients, mean (SD)</td>
<td>-</td>
<td>43.53 (23.54)</td>
<td>38.99 (15.80)</td>
<td>0.53</td>
</tr>
<tr>
<td>Intoxication on admission % (n)</td>
<td>0 (0)</td>
<td>7.8 (23)</td>
<td>25.0 (14)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Admission to intensive care unit % (n)</td>
<td>20.1 (28)</td>
<td>33.5 (108)</td>
<td>77.4 (48)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

WBCT = whole body computed tomography
Figure 12. Boxplot of ISS according to risk group after subdivision into the studied groups.

Table 3. Patient characteristics according to mechanism of injury. After subdivision into the studied groups

<table>
<thead>
<tr>
<th></th>
<th>Unprotected traffic victim</th>
<th>Protected traffic victim</th>
<th>Fall &lt;3m</th>
<th>Fall &gt;3m</th>
<th>Other (crush, blunt, SW)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=154)</td>
<td>(n=229)</td>
<td>(n=60)</td>
<td>(n=40)</td>
<td>(n=40)</td>
<td></td>
</tr>
<tr>
<td>Age, mean, years (SD)</td>
<td>33.6 (20.6)</td>
<td>35.0 (19.2)</td>
<td>44.5 (25.8)</td>
<td>43.3 (19.2)</td>
<td>36.1 (19.5)</td>
<td>0.002</td>
</tr>
<tr>
<td>Male gender % (n):</td>
<td>64.3 (99)</td>
<td>57.5 (132)</td>
<td>63.3 (38)</td>
<td>95.0 (38)</td>
<td>82.5 (33)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Examined with whole body CT % (n)</td>
<td>60.4 (93)</td>
<td>51.5 (118)</td>
<td>50.0 (30)</td>
<td>72.5 (29)</td>
<td>50.0 (20)</td>
<td>0.065</td>
</tr>
<tr>
<td>Injury on whole body CT % (n)</td>
<td>47.3 (44)</td>
<td>28.8 (34)</td>
<td>50.0 (15)</td>
<td>72.4 (21)</td>
<td>60.0 (12)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Specific radiological exams % (n)</td>
<td>61.7 (95)</td>
<td>46.3 (106)</td>
<td>56.4 (34)</td>
<td>62.5 (25)</td>
<td>52.5 (21)</td>
<td>0.033</td>
</tr>
<tr>
<td>Injury Severity Score, mean (SD)</td>
<td>5.3 (8.5)</td>
<td>3.5 (9.6)</td>
<td>5.2 (10.7)</td>
<td>8.0 (6.7)</td>
<td>7.7 (9.2)</td>
<td>0.009</td>
</tr>
<tr>
<td>Intoxication on admission % (n)</td>
<td>8.6 (12)</td>
<td>4.8 (10)</td>
<td>7.1 (4)</td>
<td>16.2 (6)</td>
<td>17.6 (6)</td>
<td>0.031</td>
</tr>
<tr>
<td>Admission to intensive care unit % (n)</td>
<td>36.4 (56)</td>
<td>30.1 (69)</td>
<td>41.7 (25)</td>
<td>42.5 (17)</td>
<td>42.5 (17)</td>
<td>0.230</td>
</tr>
</tbody>
</table>

Almost half of all patients (229/523) were exposed to MVC and they had a mean ISS of 3.5 (9.6 SD) and 163 patients (71.1 %) had no significant injuries (ISS ≤ 1). Forty fall injuries from >3 m with a mean ISS of 8.0 (6.7 SD) were identified, and 9 (22.5 %) had no significant injuries (ISS ≤ 1).
There was no difference in rate of injury findings between the hospitals. More patients were admitted for observation or treatment at the county hospital, with a large discrepancy in intensive care admissions (58 % county hospital vs 14.3 % university hospital, p < 0.001).

Of the total of 523 patients, only 47 patients (9.0 %) did not go through any radiological exams and WBCT was performed in 290 patients (55.4 %), and showed traumatic findings in 125 patients (43.1 % of those examined with WBCT).

Patients examined with WBCT in all risk groups, tabulated in table 4, had no difference in age or sex, but there was a trend towards younger patients in the low risk group (p = 0.099). Overall, mean ISS was higher in patients examined with WBCT 6.3 (10.7 SD) compared to patients not examined with WBCT 3.1 (6.4 SD). In the low risk group, there was no difference in ISS between patients examined with WBCT 1.2 (1.7 SD) and those who were not 0.8 (1.8 SD). No injuries were found on any of the WBCT performed in the low risk group, and at follow-up of 36 months or more, there was no finding of missed injuries in this group.

Table 4. Patient characteristics in patients examined with WBCT.

<table>
<thead>
<tr>
<th></th>
<th>Low risk group (n=45)</th>
<th>Intermediate risk group (n=194)</th>
<th>High risk group (n=51)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age – mean, years (SD)</td>
<td>32.7 (19.6)</td>
<td>39.4 (19.9)</td>
<td>36.1 (19.4)</td>
<td>0.099</td>
</tr>
<tr>
<td>Male gender % (n):</td>
<td>66.7% (30)</td>
<td>70.6% (137)</td>
<td>76.5% (39)</td>
<td>0.560</td>
</tr>
<tr>
<td>Injury Severity Score, mean (SD)</td>
<td>0.96 (1.02)</td>
<td>4.86 (7.17)</td>
<td>16.71 (17.72)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Injury on whole body CT % (n)</td>
<td>0% (0)</td>
<td>44.8% (87)</td>
<td>74.5% (38)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Paper II

Response rate
The response rates range between 92.3% for Finland and 23.8% for Denmark. The Nordic hospitals had a response rate of 60.2% (56/93), and the non-Nordic countries had a response rate of 80% (8/10).

WBCT official guidelines
An alert policy for trauma patients that can be set off either from the ED or the local ambulance service to optimize the staffing in the resuscitation room was present in 52 (96.4%) of the 56 responding Nordic hospitals and in seven (87.5%) of the eight non-Nordic hospitals. Official guidelines for when it is indicated to perform a WBCT were present in 47 (83.9%) of the Nordic hospitals (table 5) and in six (75.0%) of the non-Nordic hospitals.
Table 5. Guidelines for indications to perform WBCT and distribution for different hospital categories in the Nordic countries.

<table>
<thead>
<tr>
<th>Official guidelines for WBCT</th>
<th>Hospitals, n (%)</th>
<th>University hospital</th>
<th>District hospital</th>
<th>Local hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departmental guidelines</td>
<td>27 (48.2%)</td>
<td>9/16</td>
<td>13/29</td>
<td>5/11</td>
</tr>
<tr>
<td>Regional guidelines</td>
<td>16 (28.6%)</td>
<td>1/16</td>
<td>12/29</td>
<td>3/11</td>
</tr>
<tr>
<td>Both</td>
<td>4 (7.1%)</td>
<td>2/16</td>
<td>2/29</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No guidelines, but use WBCT</td>
<td>8 (14.3%)</td>
<td>4/16</td>
<td>2/29</td>
<td>2/11</td>
</tr>
<tr>
<td>Don’t know</td>
<td>1 (1.8%)</td>
<td>0</td>
<td>0</td>
<td>1/11</td>
</tr>
</tbody>
</table>

Of all the hospitals that responded, 46 (71.9%) answered that they perform WBCT after the primary survey. Survey data when WBCT is performed in the Nordic and non-Nordic countries are presented in Figure 13.

Figure 13. When WBCT is performed

Criteria to perform WBCT

The criteria used for deciding if WBCT should be performed varied between hospitals (table 6). The most common criterion used was mechanism of injury. Three hospitals responded that they only use this specific criterion.

Table 6. Criteria used for deciding if WBCT should be performed.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Nordic hospitals, n (%)</th>
<th>Non-Nordic hospitals, n (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism of injury</td>
<td>52 (94.5%)</td>
<td>6 (75%)</td>
<td>58 (92.1%)</td>
</tr>
<tr>
<td>Abnormal vital signs</td>
<td>49 (89.1%)</td>
<td>7 (87.5%)</td>
<td>56 (88.9%)</td>
</tr>
<tr>
<td>Anatomical site of injury</td>
<td>37 (67.3%)</td>
<td>5 (62.5%)</td>
<td>42 (66.7%)</td>
</tr>
<tr>
<td>Presence of multiple injuries</td>
<td>46 (83.6%)</td>
<td>7 (87.5%)</td>
<td>53 (84.1%)</td>
</tr>
<tr>
<td>Other</td>
<td>7 (12.7%)</td>
<td>3 (37.5%)</td>
<td>10 (15.9%)</td>
</tr>
</tbody>
</table>
Protocols for WBCT

All hospitals answered that they use intravenous contrast routinely with a standardized volume intra-venous contrast in 7/8 (87.5%) of the non-Nordic trauma centers. In the Nordic hospitals 30 of 55 (54.5%) use a standardized dose and 25 (45.5%) personalize the dose depending on age, weight, gender, and renal function. Table 7 shows the different regimes on how to visualize and use contrast medium in the WBCT.

Table 7. How different body parts are visualized in Nordic hospitals (multiple choices allowed)

<table>
<thead>
<tr>
<th>Body part</th>
<th>Without contrast</th>
<th>Arterial phase</th>
<th>Venous phase</th>
<th>Combined arterial and venous phase</th>
<th>Excretory phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>54 (98.2%)</td>
<td>1 (1.8%)</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td>Neck</td>
<td>42 (76.4%)*</td>
<td>7 (12.7%)</td>
<td>3 (5.5%)</td>
<td>3 (5.5%)**</td>
<td>n/a</td>
</tr>
<tr>
<td>Thorax</td>
<td>0</td>
<td>19 (34.5%)</td>
<td>26 (47.3%)</td>
<td>10 (18.2%)***</td>
<td>n/a</td>
</tr>
<tr>
<td>Upper abdomen</td>
<td>0</td>
<td>9 (16.4%)</td>
<td>28 (50.9%)</td>
<td>15 (27.3%)***</td>
<td>9 (16.4%)****</td>
</tr>
<tr>
<td>Lower abdomen (excluding pelvis)</td>
<td>0</td>
<td>6 (10.9%)</td>
<td>33 (60.0%)</td>
<td>12 (21.8%)***</td>
<td>9 (16.4%)****</td>
</tr>
<tr>
<td>Lower extremity*****</td>
<td>0</td>
<td>0</td>
<td>1 (1.8%)</td>
<td>1 (1.8%)</td>
<td></td>
</tr>
</tbody>
</table>

* Eight (14.5%) of the hospitals added that they perform neck scanning in arterial phase (CT angiography) if there is any sign of cervical injury in the first scan.
** Two of the hospitals use a split bolus technique.
*** Six of the hospitals that combine arterial and venous phase commented that they use a split bolus technique.
**** Seven of the hospitals that scan in excretory phase do this if there is a suspected renal collecting system injury.
***** Fifty-three (96.4%) do not include lower extremities routinely, but perform scans if there are suspected injuries.

Location of CT scanner

The CT scanner was located inside or adjacent to the ED in 33 (60.0%) of the responding Nordic hospitals. Adjacent was defined as on the same floor and within 50 m from the ED. All non-Nordic trauma centers had a CT scanner located near the ED, two commented that the scanner is located inside the trauma room.

Radiation

The average radiation dose to the patient during WBCT defined as the average Dose Length Product (DLP) (milligray [mGy] x cm) was reported by 37 (60%) of responding hospitals and four (50%) of the responding trauma centers. This is presented in Table 8.
Table 8. Radiation dose (DLP; mGy x cm) from WBCT in Nordic hospitals and in non-Nordic trauma centers

<table>
<thead>
<tr>
<th>Hospitals (n)</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nordic</td>
<td>33</td>
<td>3600</td>
<td>900</td>
<td>1838</td>
</tr>
<tr>
<td>Non-Nordic</td>
<td>4</td>
<td>2750</td>
<td>1700</td>
<td>2200</td>
</tr>
</tbody>
</table>

Need for national/international guidelines

In the last part of the survey responders were asked their view of the need for common guidelines concerning WBCT and if their radiology department would be interested in adopting new guidelines in the future. Some 89.1% agree regarding the need for national/international guidelines and 78.2% would be interested in adopting new guidelines in the future.

Paper III

Out of a total of 1461 trauma patients, 37 were excluded due to various reasons (lack of examination prior to discharge (14), secondary trauma patients (8), not being subject to trauma (6), double registration (2), dead on arrival (1), patients with blocked medical records (2) or with protected identity (4).

A total of 1424 patients were thus included in the study out of which 73 (5.1%) patients activated a full trauma team, 732 (51.4%) activated a limited trauma team and 619 (43.5%) did not trigger activation of a trauma team. Full trauma team was activated for all patients who received an ISS of 75 (fatal injuries) and patients with full TTA were evenly distributed with a mean ISS of 23.5 (21.1 SD).

A limited trauma team was activated 732 times, and the mean ISS was 3.5 (5.3 SD). The main findings are in the over- and undertriage according to the Matrix method in table 9. Fall injuries >3m have a tendency to be undertriaged. MVCs have a tendency to be overtriaged and the undertriage is well below acceptable limits of 5%.
Table 9. Over- and undertriage with the Matrix method according to MOI. Green color represents over- and undertriage at acceptable levels.

<table>
<thead>
<tr>
<th>Mechanism of injury</th>
<th>Undertriage (%)</th>
<th>95% CI</th>
<th>Overtriage (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle crashes</td>
<td>0.4</td>
<td>0.1 - 0.9</td>
<td>47.1</td>
<td>27.8 - 77.0</td>
</tr>
<tr>
<td>Motorcycle crashes</td>
<td>5.0</td>
<td>1.4 - 12.3</td>
<td>0.0</td>
<td>0.0 - 52.2</td>
</tr>
<tr>
<td>Bicycle crashes</td>
<td>3.8</td>
<td>1.3 - 8.7</td>
<td>0.0</td>
<td>0.0 - 45.9</td>
</tr>
<tr>
<td>Horse accidents</td>
<td>4.9</td>
<td>1.3 - 12.0</td>
<td>100.0</td>
<td>- - -</td>
</tr>
<tr>
<td>Pedestrians hit</td>
<td>5.9</td>
<td>0.1 - 28.7</td>
<td>20.0</td>
<td>0.5 - 71.6</td>
</tr>
<tr>
<td>Fall injuries &lt;3m in height</td>
<td>5.8</td>
<td>3.3 - 9.4</td>
<td>50.0</td>
<td>1.3 - 98.7</td>
</tr>
<tr>
<td>Fall injuries &gt;3m in height</td>
<td>11.6</td>
<td>3.9 - 25.1</td>
<td>27.3</td>
<td>6.0 - 61.0</td>
</tr>
<tr>
<td>Other injuries</td>
<td>4.7</td>
<td>2.1 - 9.1</td>
<td>38.5</td>
<td>20.2 - 59.4</td>
</tr>
<tr>
<td>All injuries</td>
<td>2.7</td>
<td>1.9 - 3.8</td>
<td>32.9</td>
<td>22.3 - 44.9</td>
</tr>
</tbody>
</table>

The compliance to full trauma team alert criteria was 80% (95%CI 68-88%). For activating limited trauma team, it was 54% (95%CI 51-58%). There were also differences between various MOI displayed in table 10.

Table 10. Compliance to alert criteria. Yellow represents suboptimal compliance (<60%)

<table>
<thead>
<tr>
<th>Correct level of alert</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full trauma team activation</td>
<td>0.80</td>
</tr>
<tr>
<td>Limited trauma team activation</td>
<td>0.54</td>
</tr>
<tr>
<td>No trauma team activation</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Immobilization on a long spine board or with Kendrick Extrication Device (KED) was an independent risk factor for mistriage with an odds-ratio of 1.75 (95% CI 1.41 – 2.17). See table 11 for details. Patients brought in by anesthesiologist in helicopter emergency service, or patients who only received a
semi-rigid neck collar for immobilization did not statistically differ in odds-ratio regarding mistriage.

Table 11. Odds-ratio for mistriage

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Odds-Ratio</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equestrian accidents</td>
<td>3.05</td>
<td>1.94 - 4.80</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Low fall injuries (&lt;3m in height)</td>
<td>1.51</td>
<td>1.14 - 1.99</td>
<td>0.004</td>
</tr>
<tr>
<td>Blood alcohol &gt;15mmol/l</td>
<td>2.17</td>
<td>1.49 - 3.13</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patient immobilized on long spine board/KED</td>
<td>1.75</td>
<td>1.41 - 2.17</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Only risk factors with significant Odds-Ratio are included in this table for full table, please see paper III

Paper IV

During the study period, 1948 trauma patients were registered in SweTrau at the participating centres, 66 (3.4%) of which were excluded. The numbers of patients initiating full TTA, limited TTA and no TTA before and after change of trauma criteria are presented in the flow chart, figure 14.

![Flowchart of patients included in the study](image)

Figure 14. Flowchart of patients included in the study

The demographics of included patients showed differences in the proportion of male patients activating a limited trauma team, a difference in penetrating trauma and in ISS of limited TTA patients. There was no difference in mortality, table 12.
Table 12. Study population demographics

<table>
<thead>
<tr>
<th></th>
<th>Former criteria (n=1187)</th>
<th>New criteria (n=695)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age - median, years (IQR):</td>
<td>36 (21-60)</td>
<td>40 (22-61)</td>
<td>0.173</td>
</tr>
<tr>
<td>Full trauma team activation</td>
<td>40.5 (23-63)</td>
<td>43 (22-62)</td>
<td>0.726</td>
</tr>
<tr>
<td>Limited or no trauma team activation</td>
<td>36 (21-59)</td>
<td>40 (21-61)</td>
<td>0.129</td>
</tr>
<tr>
<td>Male gender % (n):</td>
<td>59.0 (704)</td>
<td>64.6 (450)</td>
<td>0.013</td>
</tr>
<tr>
<td>Penetrating trauma % (n):</td>
<td>2.4 (29)</td>
<td>7.8 (54)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Glasgow Coma Scale in Emergency Department, % (n):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal or minimal injury (GCS 15)</td>
<td>84.4 (1037)</td>
<td>82.3 (572)</td>
<td>0.003</td>
</tr>
<tr>
<td>Mild injury (GCS 13-14)</td>
<td>5.1 (60)</td>
<td>8.6 (60)</td>
<td>0.002</td>
</tr>
<tr>
<td>Moderate injury (GCS 9-12)</td>
<td>1.1 (13)</td>
<td>3.6 (25)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Severe injury (GCS 8 or below)</td>
<td>2.1 (25)</td>
<td>2.9 (20)</td>
<td>0.290</td>
</tr>
<tr>
<td>ASA-classification, median (IQR):</td>
<td>1 (1-2)</td>
<td>1 (1-2)</td>
<td>0.254</td>
</tr>
<tr>
<td>Injury Severity Score, median (IQR):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full trauma team activation</td>
<td>8 (1-16)</td>
<td>9 (1-16)</td>
<td>0.977</td>
</tr>
<tr>
<td>Limited or no trauma team activation</td>
<td>1 (0-4)</td>
<td>2 (1-8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>New Injury Severity Score, median (IQR):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full trauma team activation</td>
<td>9 (3-25)</td>
<td>9 (2-21)</td>
<td>0.848</td>
</tr>
<tr>
<td>Limited or no trauma team activation</td>
<td>2 (0-4)</td>
<td>3 (1-9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>30-day mortality % (n):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full trauma team activation</td>
<td>13.8 (20)</td>
<td>12.1 (17)</td>
<td>0.662</td>
</tr>
<tr>
<td>Limited or no trauma team activation</td>
<td>1.7 (18)</td>
<td>2.6 (14)</td>
<td>0.268</td>
</tr>
</tbody>
</table>

IQR=Interquartile range, ASA= American Society of Anesthesiologists Physical Status

Over- and undertriage

Overtriage was 71.3% (107/150 patients) with the former TTA criteria and 72.2% (104/144 patients) with the new TTA criteria, p=0.866. Undertriage calculated with the Matrix method was 4.8% (50/1037) with former criteria and 7.1% (39/551) with new criteria, p=0.063. 53.8% (50/93) of severely injured patients (ISS>15) did not initiate full-TTA with former, vs 49.4% (39/79) with new criteria, p=0.565.

Subgroup analysis of undertriage

Undertriaged patients according to injury mechanism are presented in figure 15. Road traffic accidents constitute 55.3% (656/1187) of all patients with former criteria and 52.9% (368/695) with new criteria. Ten patients subject to road traffic accidents were undertriaged with former and nine with new criteria, p=0.204. Patients subject to low fall injury constituted 13.8% of the
trauma patients (164/1187) with former and 12.2% (85/695) with new criteria, \( p = 0.327 \). Eighteen of these patients were undertriaged with both former and new criteria \( p = 0.051 \).

![Figure 15](image)

**Figure 15.** Proportion of undertriaged patients based on mechanism of injury. Error bars indicate 95% confidence interval.

### Risk factors for undertriage

Binary logistic regression analyses of risk factors for undertriage indicate a higher risk for undertriage in patients \( \geq 60 \) years of age, table 13. There was a trend for increased risk for undertriage in patients with fall injury.

### Table 13. Odds-ratio of risk factors for undertriage

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Odds-ratio</th>
<th>95% CI</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanism of injury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor vehicle accident</td>
<td>0.431</td>
<td>0.15 - 1.27</td>
<td>0.126</td>
</tr>
<tr>
<td>Motorcycle accident</td>
<td>0.743</td>
<td>0.19 - 2.84</td>
<td>0.664</td>
</tr>
<tr>
<td>Bicycle accident</td>
<td>0.546</td>
<td>0.13 - 2.35</td>
<td>0.416</td>
</tr>
<tr>
<td>Pedestrian hit</td>
<td>0.563</td>
<td>0.06 - 4.99</td>
<td>0.606</td>
</tr>
<tr>
<td>Gunshot wound</td>
<td>0.000</td>
<td>0.00 -</td>
<td>1.000</td>
</tr>
<tr>
<td>Stab wound</td>
<td>0.000</td>
<td>0.00 -</td>
<td>1.000</td>
</tr>
<tr>
<td>Low fall injury</td>
<td>2.704</td>
<td>1.00 - 7.35</td>
<td>0.051</td>
</tr>
<tr>
<td>High fall injury</td>
<td>1.681</td>
<td>0.63 - 4.47</td>
<td>0.298</td>
</tr>
<tr>
<td>Age ( \geq 60 ) years</td>
<td>2.886</td>
<td>1.74 - 4.79</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ASA-classification( \geq 3 )</td>
<td>0.935</td>
<td>0.53 - 1.66</td>
<td>0.818</td>
</tr>
</tbody>
</table>

ASA = American Society of Anesthesiologists Physical Status
Reduction in TTA – who was affected?
The reduction in limited TTA with the new criteria was from 988 patients to 531 patients (46% reduction). In order to evaluate this reduction, it is important to know which patients did not initiate a TTA. The overall rate of overtriage was the same with former and new TTA criteria, and there was no significant difference in undertriage with former and new criteria. By plotting a bar chart with ISS groups of 0-2 and 3-75, the results are visualized in figure 16. 88% of the reduction occurred in patients with ISS <3.

![Figure 16](image.png)

*Figure 16. Number of patients grouped by Injury Severity Score and paneled by former and new criteria.*
General discussion

Excellent trauma care is not only about performing the right measures in each specific patient situation, but also about carefully planning and managing resources, both in their utilization and the time frame in which they are used. When a patient is subject to traumatic injuries the clock starts ticking and if the patient is actively bleeding the time until the bleeding is stopped affects outcome. To meet this challenge, it is imperative to have the right resources present at the right time. This is where the inclusive trauma system comes into play. You do not have time to set up the plan based on the known facts of every incidence, but instead you have to have a sturdy plan on how trauma is managed in your region that starts with preventive measures and end after rehabilitation of the trauma patient.

Whole body computed tomography

The liberal use of WBCT in patients subject to trauma is a key adjunct in delivering the best trauma care. WBCT is crucial in finding occult injuries when distracting injuries are present, or when the patient is influenced by alcohol or other drugs.

Disadvantages in the liberal use of WBCT include exposition to ionizing radiation. Population based estimates suggest that approximately 0.1% of the current cancer incidence is due to medical radiation exposure. This provides medical staff with a dilemma: Should one use WBCT, and thus expose the patient to radiation averaging about 2000 mGy x cm? The advantages are imminent as the WBCT will help doctors find and map patient injuries, while the disadvantages are risks calculated by data extrapolation from massive radiation exposures, and with the uncertainties associated with this method. The benefit from WBCT exceeds the risks if there is a substantial risk that the patient is seriously injured. At the same time, obviously CT scanning of the whole population without an indication has risks that exceeds the benefits. According to the Swedish Radiation Safety Authority regulatory code in medical practice, medical practitioners are obligated to keep the radiation dose as low as reasonably achievable (ALARA principle), but at the same time ensuring that the needed diagnostic information is obtained.

In paper I, we concluded that if the patient did not have clinical signs of serious injury, was conscious and alert and with no signs of alcohol- or drug
intoxication, there were no serious injuries missed regardless of whether a WBCT scan was performed or not. Still, the liberal use of WBCT lead to some incidental findings requiring further investigations and in a few cases even contributed to finding cancer present without symptoms. At the same time, findings in WBCT also lead to adverse effects in several patients and one patient was treated for a non-existing cervical fracture with 6 weeks of c-spine immobilization.

A WBCT without injury findings can be considered an unnecessary examination, but it still gives a lot of information. The results can be used to discharge a patient instead of admitting, and it can be reassuring to both patient and doctor.

One cannot discuss radiation without considering the age of the patients because radiation induced damage to cell proliferation is an accumulative process. The mean age of all trauma alert patients in paper I and III (n=1328) is 39.5 years and with the current life expectancy in Sweden of 81.8 years, they have an average life expectancy of more than 42 years.

Triage

Triage is a resource allocation system where fine resources are rationed based on previous experience and science. Every region of the world has their panorama of trauma, and the triage system is influenced by this, but not always in an optimal way. The American college of surgeons has developed a triage algorithm well suited for the American panorama of trauma at the time the algorithm was developed. But is this algorithm suitable for other regions with different prevalence of type injuries? Are mechanisms of injury constant over time? The answer to both questions is both yes and no, since the triage algorithms are based on physiology, with boundaries that are constant regardless of the MOI, type specific injuries that have been proven to accurately predict serious injury, and MOI criteria – incidents we consider dangerous based on previous experience. Derangements in physiology are with few exceptions a proof of that the trauma patient has sustained injuries and it is good resource management to gather the full trauma team for the initial assessment. The injuries in themselves can be serious, but enough time has not yet passed for the patient to be physiologically deranged.

The same is true for type specific injuries as they accurately predict the seriously injured patient. If there are anatomic injuries such as multiple fractures, or a truncal gunshot wound, present already at the scene of injury, the patient is at high risk of serious injuries and will benefit from a multidisciplinary approach in the initial assessment.
Deranged physiology in combination with type specific injuries have a high probability for the patient to be seriously injured\textsuperscript{47, 60}. This is also true in a military environment where admission physiology criteria predict both mortality and resource utilization\textsuperscript{61}.

Mechanisms of injury are not constant over time. In the early 20\textsuperscript{th} century, accidents with horse and carriage were common, and working in the fields with animals and primitive machinery caused injuries uncommon today. The recurring eruption of war has introduced mechanisms of falling debris in shelling, direct injuries due to explosions and penetrating trauma from all the devices developed to assist in man’s inhumanity to man. The general suffering during war also contribute by the ever-present fatigue of people where their basic needs for sleep and food are not met. In addition, the sanitary conditions in war will inevitably lead to contaminations of injuries and the need for alternate treatment compared to peacetime conditions\textsuperscript{62}. The luxury of allocating resources to patients based solely on MOI has not been an option under strenuous circumstances where the needs far exceed available resources.

Motor vehicle crashes are the most common mechanism of injury globally today. The number of deaths by this MOI is still increasing in the developing world, while there is a decrease in MVC deaths in the western world.\textsuperscript{2} The speed at which cars travel does not differ much with the income status of the country, if anything, average speeds tend to be higher in countries with a decreasing death toll. The technical advances in modern cars in combination with the mandatory use of safety equipment are key factors in reducing injuries and death in traffic.\textsuperscript{2} In combination with primary preventive measures such as separation of opposing lanes and roundabouts the sole mechanism of
injury presented by MVCs has a decreasing predictive value for serious injury in the most developed countries.\textsuperscript{63}

Over the last decades the population in the western world are getting older, and the panorama of trauma is changing with a decrease in MVC and an increase in fall injuries\textsuperscript{64}.

It has become apparent that the trauma alerts criterion on mechanism of injury needed to be revised in the Nordic countries. As we showed in paper III, the risk for serious injury in a patient without deranged physiology or type specific injuries following a MVC is only 0.4% in our region, and the allocation of resources solely based on MOI can be questioned.

A change in triage algorithms for MOI could decrease resource utilization by 50% in less activation of limited trauma teams\textsuperscript{65}, but this can be questioned in a two tier alert system, as the resources needed in treating a patient subject to high energy trauma is essentially the same if it is initiated by a limited trauma alert or as a normal examination without an alert. The major difference is in timing; since the alert patient is examined immediately, and the non-alert patient is examined when it is appropriate given the needs of other patients at the ED.

When MOI triggers a limited trauma team it does not affect overtriage, calculated by the matrix method in a two-tier trauma alert system.

Studies on over- and undertriage are summarized in table 14. The focus of the table is on Nordic studies as these patients are the most similar to patients in our paper III and IV. The methods for calculating over- and undertriage varies in different studies, and in table 14, we have chosen to include studies where undertriage is calculated with the matrix method and/or as the proportion of severely injured patients who did not initiate a full TTA compared to all severely injured patients.

Table 14. Studies on triage criteria with over- and undertriage estimations

<table>
<thead>
<tr>
<th>First author, reference</th>
<th>Year</th>
<th>N</th>
<th>Country</th>
<th>Death (%)</th>
<th>Overtriage (%)</th>
<th>Undertriage matrix (%)</th>
<th>Undertriage 1-PPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis JW\textsuperscript{66}</td>
<td>2017</td>
<td>7,031</td>
<td>USA</td>
<td>5.5</td>
<td>45</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Dehli T\textsuperscript{67}</td>
<td>2016</td>
<td>324</td>
<td>Norway</td>
<td>5.6</td>
<td>74</td>
<td>7</td>
<td>28</td>
</tr>
<tr>
<td>Granström A\textsuperscript{68}</td>
<td>2011</td>
<td>1,408</td>
<td>Sweden</td>
<td>5.1</td>
<td>74</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Granström A\textsuperscript{68}</td>
<td>2013</td>
<td>1,466</td>
<td>Sweden</td>
<td>3.7</td>
<td>52</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>van Laarhoven JJ\textsuperscript{69}</td>
<td>2014</td>
<td>1,607</td>
<td>Netherlands</td>
<td>n.a</td>
<td>40</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Brown JB\textsuperscript{70}</td>
<td>2011</td>
<td>1,086,704</td>
<td>USA</td>
<td>4.6</td>
<td>22</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Rehn M\textsuperscript{71}</td>
<td>2012</td>
<td>1,812</td>
<td>Norway</td>
<td>5.2</td>
<td>65</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Dehli T\textsuperscript{48}</td>
<td>2011</td>
<td>441</td>
<td>Norway</td>
<td>6.6</td>
<td>71</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Curtis K\textsuperscript{72}</td>
<td>2010</td>
<td>5,233</td>
<td>Australia</td>
<td>69</td>
<td>8</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Linder F</td>
<td>2018</td>
<td>1,424</td>
<td>Sweden</td>
<td>1.1</td>
<td>33</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Linder F</td>
<td>2018</td>
<td>1,187</td>
<td>Sweden</td>
<td>3.2</td>
<td>71</td>
<td>5</td>
<td>54</td>
</tr>
<tr>
<td>Linder F</td>
<td>2018</td>
<td>695</td>
<td>Sweden</td>
<td>4.5</td>
<td>72</td>
<td>7</td>
<td>49</td>
</tr>
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</table>
Undertriage can also be assessed by evaluating the proportion of immediate life-saving interventions performed on patients not triggering full TTA. This method is substantially different from methods using injury severity scoring algorithms and undertriage is usually below 2% in studies using this method\textsuperscript{46, 73}. Some procedures such as resuscitative thoracotomy is easy to categorize, while other measures such as placement of a central line can be effectuated immediately or several hours later, or even omitted leaving a substantial observational bias in the assessment of undertriage. Just because the intervention was performed does not guarantee it had to be done at that time or in that manner.

The formation of a Swedish expert-panel with participation from some 20 professional organizations involved in trauma care, with a mission to go through the literature regarding triage and evidence for every specific criterion used, was successful, even with limited or even contradictory evidence regarding which system is superior in trauma triage\textsuperscript{74}. The presentation of the consensus-based TTA criteria was received with enthusiasm in Sweden, and the implementation was uneventful.

AIS-scoring and triage bias

Paper I and III are both retrospective studies where AIS was used for scoring injuries and subsequently to calculate ISS and NISS. The scoring was performed by the authors and this introduces a bias. The AIS 2005 rev 2008 was used and even though all cases with ISS>9 was thoroughly evaluated by two or more authors with medical professions, we had not attended an AIS classification course prior to these studies. This was remediated before the start of the study reported in paper IV, where the scoring is of better quality, performed only by accredited personnel and with a specific program in the web-based entry-module for SweTrau. The scoring of difficult cases at all including sites was also validated by re-scoring by accredited personnel from another including site.

The risk-group stratification in paper I is based partially on triage and in paper III triage decisions affect the rates of over- and undertriage. The triage was with few exceptions performed by a senior nurse in the ED, or by prehospital staff and the correctness in these decisions, made in a stressful environment, with limited information at hand, is difficult and prone to error. As we showed in paper III, the compliance to alert-criteria was only 54% regarding limited TTA introducing a bias. The previous studies listed in table 14, as well as other studies on over- and undertriage are prone to the same error and while the numbers reflect the actual outcome of triage, it is virtually impossible to evaluate the TTA criteria with this questionable compliance and lack of information regarding the specific criteria initiating the alert.
Ethical considerations

In order to follow up the change in trauma team activation criteria a randomized controlled study would have been preferable. The alert criteria had recently been changed in Norway, based on clinical judgment and best practice, but without a follow-up study.

Ethical considerations in a prospective triage study included the dilemma of informed consent. It cannot be considered ethical to ask the trauma patient to participate in a study during an accident, and the randomization must therefore take place before the patient is informed and informed consent to inclusion in the study must be obtained at a later stage. This was denied by the ethical review board and an alternative approach was initiated where the study was performed within the routine clinical practice and a planned change of TTA criteria. The stepped wedge study design was chosen and proved to be an efficient method to prospectively study a clinical change in play.

Compliance to alert criteria

Triage criteria, guidelines and protocols have been implemented for the reasons of safety, standardization and resource management. Protocol, and protocol adherence in trauma triage has been identified as a future research priority, and in paper III we have tried to study compliance to alert criteria. Our studies show that compliance to set parameters is an important factor in evaluation of data. For instance, compliance to limited TTA criteria in paper III is only 54% (95%CI 51 – 58%). Conclusions drawn on the algorithm itself will be weak if the compliance is not sufficient. In this case, 46% of patients triaged to limited alert according to present criteria were not in the right triage group. 21 limited alert patients meet the criteria for full trauma alert. Some 193 limited trauma alert patients should not have activated any trauma alert. In paper III we re-triaged the patients based on the prehospital reports, and with the Matrix method, we concluded that the results on over- and undertriage were still valid despite the lack of compliance to alert criteria in all groups. Patient demographics as well as ISS and NISS in our two-tier trauma alert system is well in line previously published data, in a Nordic, European and North American setting with some variations regarding prevalence of penetrating trauma.

The reasons for this lack of compliance to alert criteria may be found in the circumstances when the alert is initiated. First, if the telephone report to the triage nurse lacks sufficient data, the result could be an incorrect alert. Second, routines and guidelines for trauma alert activation may come in conflict with routines for management of the immobilized patient or routines to prevent emergency room overcrowding. In a study on compliance to inter-hospital transfer guidelines before and after initiation of a new protocol the overall
compliance was between 62-67%\(^7^9\). Studies on compliance to trauma alert criteria in a modern medical environment are scarce, but a recent study from the University of Minnesota and the University of Michigan including 51,792 patients at 29 trauma centers in Michigan, USA during 2014-2016 showed compliance to full TTA ranging between 51-82\%\(^8^0\). These results support our conclusion in paper III regarding 80\% as an acceptable level of compliance to full TTA.

If the patient is immobilized in transport or on admission, she requires constant surveillance until immobilizing measures have been terminated. In a situation where the patient is subject to an MVC, and is immobilized but does not meet the criteria for orange trauma alert, it can be argued to initiate a limited alert anyway, because the patient will then receive an immediate evaluation upon arrival and immobilization can be terminated. If an alert is not initiated, the receiving nurse will be designated for this patient only until there is a doctor available for examination. There may be other patients with greater needs in the ED and the waiting time can sometimes be substantial. During this time, staff is prevented from dealing with other patients. An interesting approach in addressing the problem with immobilization is the use of the Canadian c-spine rule by nurses to reduce unnecessary immobilization in the ED\(^8^1\). This would enable the ED nurse to discontinue with immobilization after the patient has been evaluated, thereby resolving the issue of constant surveillance of the immobilized patient and may affect compliance to alert criteria.

The survey presented in paper II also presses an issue of compliance. In the vast majority of hospitals included in the survey, ATLS is the base at which the delivery of trauma care is performed. ATLS clearly state that WBCT is an adjunct to the secondary survey. Still, 12.5\% of Nordic countries and 10.9\% of non-Nordic countries report that they perform WBCT before or as a part of the primary survey. If this is due to a local practice in conflict with the ATLS concept, or a misinterpretation on the responders’ part on how their own protocol works, is unclear.

The seasonal distribution in trauma

Trauma is not evenly distributed, but rather seasonal in prevalence. In paper IV this seasonal variance had to be accounted for in order not to over- or underestimate the results of the study. SweTrau was used to show the seasonal variation over the year and to link it with the stepped wedge inclusion periods. The expected results would have been a 10\% increase in trauma prevalence without intervention. The seasonal distribution and inclusion intervals for paper IV is shown in figure 18. The variation in both number of trauma patients and type of trauma advocates a randomized trial instead of a stepped wedge cohort study, but as mentioned earlier the ethical review board and Swedish law prohibits a randomized clinical trial with a delayed informed consent. The
results in paper IV must be interpreted bearing this in mind. The number of motorcycle accidents for instance, is not evenly distributed among study groups.

Figure 18. The historic seasonal variance in TTA and the stepped wedge inclusion periods.

The Swedish Trauma Registry

SweTrau registered some 20 800 patients between 2014-2016, and to date the total number of patients registered is >30 000\textsuperscript{82}. The registration follows the Utstein template which enables studying over- and undertriage in a trauma cohort. One weakness in the current registration algorithm is that only level of trauma team activation is registered, not the specific grounds for initiating a trauma alert.

This limits the ability to evaluate the efficacy of every single specific criteria both in specificity and sensitivity. Information on mechanism of injury is present, which enabled our sub-group analysis of undertriage in paper IV, but it would be preferable if future registration contained the exact TTA criteria for future evaluation.

Until then, the Uppsala-Örebro region has agreed to include this information as a free variable starting 2018, to enable further evaluation of not only the whole package of TTA criteria but rather every specific criterion regarding specificity and sensitivity.
Figure 19. The Swedish trauma registry website for registration and data extraction.
Conclusions

The current practices in trauma care regarding triage and use of WBCT in a Nordic context has been evaluated in this thesis.

• WBCT rarely detects a significant injury in trauma patients who are mentally alert, not intoxicated nor shows signs of other than minor injuries when evaluated by a trauma-team.

• Protocols for WBCT in trauma is currently defined locally by most Nordic trauma hospitals.

• The scanning protocols differ significantly between centers but there is an interest to endorse new national guidelines for WBCT.

• The rate of undertriage in a Swedish cohort is in line with current recommendations by the American College of Surgeons Committee on Trauma.

• Further improvement of compliance to established TTA criteria may optimize resource allocation, with adequate levels of over- and undertriage.

• The newly implemented Swedish TTA criteria are safe, with levels of over- and undertriage remaining consistent after change of TTA criteria.

• The number of limited TTA diminished significantly with the new criteria, resulting in an increased efficiency in use of in-hospital resources, without compromising patient safety.

• Elderly patients subject to fall injury have a high risk for undertriage and further evaluation of TTA criteria are motivated in order to decrease undertriage in this group of patients.
Future perspectives

Triage will remain a key component in resource allocation during a foreseeable future, and even with the successful implementation of national TTA criteria, work still needs to be done in order to achieve an evidence based inclusive trauma care system.

Use of WBCT in trauma
The use of WBCT in the trauma cohort is influenced by standard operating procedures (SOP) in trauma care. The implementation of new consensus TTA criteria and guidelines limiting the use of spinal immobilization could potentially reduce the use of indiscriminate WBCT protocols and instead favor aimed investigations and thereby reducing radiation exposure. A retrospective single- or multicenter cohort study could further investigate the matter.

Evaluation of specific TTA criteria
The evaluation of the new consensus TTA criteria was based on outcome for the whole package of criteria and to some extent in regards to specific mechanisms of injury. The rates of over- and undertriage were not evaluated for every single criterion, because the information was not available in our data. A future study is in the planning process where information regarding every single criterion and its use would be gathered. The study could evaluate over- and undertriage of every single criterion, as well as the frequency at which a criterion is used. Several previous studies have concluded low fall injuries and extremes in age constitute challenges in terms of undertriage, and further studies with specific aim on patients with low fall and high age may contribute to the understanding of how to identify patients at risk. The analysis of how criteria is used would enable further adapting the consensus TTA criteria and assist in decreasing over- and undertriage.

Validation of SweTrau
The Swedish trauma registry, SweTrau, was used in paper IV, but it has not yet been externally validated. A future study with interest to anyone basing research on SweTrau would be a thorough validation with an external valida-
tion of traffic-accident in SweTrau validated against The Swedish Traffic Accident Data Acquisition (STRADA). Both registers use AIS for injury classification. The Swedish intensive care registry (SIR) could also be used. Validation against source-data could be done with re-registration and completeness and coverage should also be evaluated. The validation of SweTrau is important in future studies based on the registry.

Using the TTA criteria for pre-hospital triage?

Pre-hospital resource allocation has been addressed in the Norwegian trauma system with harmonized criteria regarding where, when and how a trauma patient should be transported. The Swedish algorithms for prehospital care is based on local protocols and lack national guidelines. The use of the TTA guidelines as pre-hospital transport algorithm and resource management directions could be studied.

The use of spinal immobilization

The reduction in spinal cord disruption during the 1970s and 1980s has been interpreted as a result of the introduction of spinal immobilization, but in more recent studies it has been questioned. A multi-center study of the new Swedish consensus based spinal immobilization guidelines with matched controls could add valuable knowledge and in conjunction with other studies serve as base for changed national immobilization guidelines. The use of pre-hospital immobilization has implications on use of TTA criteria and compliance to these guidelines. Revised guidelines regarding spinal immobilization could be studied, not only regarding the effect on spinal injury, but also on the effect on over- and undertriage and compliance to TTA criteria.
Sammanfattning på svenska (Summary in Swedish)

Trauma är den vanligaste dödsorsaken i Sverige för unga människor mellan 15–44 år och orsakar såväl stort lidande för den enskilde och anhöriga, som stora samhällskostnader. Traumavården har under de senaste årtiondena genomgått stora förändringar och överlevnaden efter svåra olyckor har förbättrats, men det är en positiv utveckling som tar stora resurser i anspråk. Genom införande av traumalarm där många olika sorters läkare och sjuksköterskor aktiveras i det initiala omhändertagandet av traumapatienter på akutmottagningen har stora resurser bundits upp i omhändertagandet och det är därför viktigt att dessa resurser riktas till rätt patienter. Frikostig användning av röntgenundersökningar för att kartlägga skador är även detta en del i modernt traumaomhändertagande.

I denna avhandling har vi specifikt tittat på utnyttjandet av helkroppsskiktröntgen vid trauma samt resursallokering till traumapatienter kallat ”triage”.

Användning av helkroppsskiktröntgen för patienter som varit med om stora olyckor utvecklades under tidigt 90-tal och har sedan dess blivit ett standardförfarande vid traumaomhändertagande. En helkroppsskiktröntgenundersökning tar cirka 20 minuter att genomföra och innebär att patienten undersöks utan och med kontrastmedel som injiceras i blodbanan. Undersökningen är mycket bra på att hitta skador orsakade av det våld patienten utsatts för, och kan även leda till upptäckt av tumörer och förändringar som ännu ej givit symptom. Samtidigt resulterar en helkroppssundersökning med skiktröntgen stora stråldoser till patienten och strålningens risker måste vägas mot undersökningens potentiella fördelar. Frågan om stråldoser är särskilt aktuell vid trauma då olyckor främst drabbar unga vuxna.

till dem patienter med de största medicinska behoven, men man behöver kon- tinuerligt följa upp att resurserna inte överutnyttjas. Än viktigare är att följa upp så att svårt skadade patienter inte missas med dessa kriterier och dess till- lämpning.

2016 genomfördes en nationell evidensgenomgång av larmkriterier för triage på sjukhus, och en expertgrupp lanserade nationella konsensus-kriterier för traumalarm nivå 1 (fullständigt) och nivå 2 (begränsat) traumalarm. Dessa kriterier har eller kommer att införas i hela Sverige, och har i denna avhandling utvärderats med avseende på säkerhet och träffsäkerhet.

Delarbete I

**Patienter utsatta för högenergetiskt trauma som vid undersökning av traumatteamet är vakna, alerta, och endast uppvisar tecken till ringa ska- dor har ingen nytta av en helkroppssiktröntgenundersökning.**


I lågriskgruppen genomfördes helkroppssiktröntgenundersökning på 32.1% av alla patienter, men ingen skada upptäcktes. I högriskgruppen genomfördes helkroppssiktröntgenundersökning på 82.3% av alla patienter och 74.5% hade skador som påvisades med undersökningen. Medelålder för patienter i lågriskgruppen var 32.5 år.

Patienter utsatta för högenergetiskt våld som är vakna, alerta, och endast uppvisar tecken till ringa skador kan observeras och undersökas på nytt vid ett senare tillfälle istället för att genomgå helkroppssiktröntgenundersökning. Detta bör särskilt beaktas hos unga människor där långtidseffekter av joniserande strålning inte kan uteslutas.
Delarbete II

Helkropps skiktröntgen är utformad efter lokala protokoll men det finns ett intresse för att utveckla nordiska riktlinjer för hur undersökningen skall genomföras.

Det finns i Norden ett flertal protokoll över hur en helkropps skiktröntgenundersökning ska genomföras vid trauma med avseende på tjocklek på snitt, användning av intravenös kontrast och i vilka faser undersökningen sedan genomförs. Varje undersökningsform har sina för- och nackdelar när det gäller att påvisa specifika skador, men de många alternativen påverkar tiden en undersökning tar, den stråldos patienten utsätts för, mängden intravenös kontrast samt ger upphov till tolkningsproblem då bilder skickas mellan sjukhus.

Genom en enkät tillfrågades 95 sjukhus i norden samt 10 internationella traumacenter. Undersökningen bestod av 23 frågor och svarsfrekvensen var 62.1%. Det förelåg lokala riktlinjer för användningen av helkropps skiktröntgen vid trauma hos 83.9% av svarande sjukhus och 94.5% av de nordiska sjukhusen hade högenergetisk skademekanism som kriterium för undersökningen.

Datortomografen var placerad i direkt anslutning till akutmottagningen hos 60% av svarande sjukhus, och det förelåg stor variation kring hur undersökningen av olika kroppsregioner genomfördes och på vilket sätt intravenös kontrast användes, men 89.1% av svarande ansåg att det vore bra med nordiska riktlinjer kring hur helkropps skiktröntgen vid trauma ska genomföras.

Stråldosen var i genomsnitt 1838 mGy x cm vid nordiska sjukhus och 2200 mGy x cm vid internationella traumacentra.

Delarbete III

Bättre följsamhet till gällande larmkriterier skulle minska antalet larm med likvärdiga nivåer på över- och undertriage.

Kriterier för traumalarman är återkommande utvärderas avseende dess träffsäkerhet att rikta resurser till svårt skadade patienter (övertriage) samt risken att missa allvarligt skadade patienter (undertriage). Träffsäkerheten i gällande larmkriterier är dock svår att utvärdera om följsamheten till kriterierna är låg då det blir en osäker koppling mellan resultaten på sjukhusnivå, och hur dessa resultat faktiskt förhåller sig till larmkriterierna.

Genom att undersöka hela traumakohorten vid Akademiska sjukhuset under 2012 och följsamheten till gällande traumalarmskriterier har larmsystemet utvärderats avseende träffsäkerhet, följsamhet till kriterier samt säkerhet. Matrixmetoden användes för beräkning av över- och undertriage.

Totalt identifierades 1461 patienter varav 1424 inkluderades i studien. 73 patienter aktiverade ett nivå 1 traumalarm, 732 aktiverade ett nivå 2 traumalarman och 619 patienter aktiverade inget traumalarm. Övertriage var 32.9% och
undertriage 2.7%. En analys av följsamheten till larmkriterier visade att Nivå 1 larm hade en följsamhet till kriterier på 80%, nivå 2 larm en följsamhet på 54% och patienter som inte utlöst traumalarf hade en följsamhet på 79%. Följsamheten får därmed anses adekvat för nivå 1 larm samt för patienter som inte utlöst något traumalarf. Däremot är följsamheten till nivå 2 larm lägre vilket sammantaget givit upphov till 172 fler larm än vad kriterierna stipulerar.

Med en bättre följsamhet till larmkriterierna skulle övertriage vara 42.6% samtidigt som undertriage skulle vara 2.3% vilket statistiskt sett är oförändrat jämfört med nuvarande utfall.

Delarbete IV

De nya nationella konsensuskriterierna för traumalarf har minskat antalet nivå 2 larm med 46% med minskad resursåtgång på sjukhus som följd. Över- och undertriage är oförändrat jämfört med tidigare kriterier.


En stickprovsanalys visade ett behov av minst 588 patienter per grupp för att kunna påvisa en skillnad i undertriage från 4–8%.

Fem sjukhus i Uppsala-Örebro region med ett primärt upptagsområde på 1 200 000 invånare ingick i studien och 1948 patienter identifierades varav 1882 patienter inkluderades. Det förelåg ingen skillnad i nivå 1 traumalarf före och efter införandet av nya larmkriterier, men nivå 2 larmen minskade med 46%. Det förelåg ingen skillnad i dödlighet och en analys kring vilka patienter som inte längre utlöste larm påvisade att 88% av dessa uppvisade en skadepoäng på 0–2 på en skala från 0–75 med svårare skador vid högre poäng.

Övertriage var 71.3 respektive 72.2% med de gamla och nya kriterierna och undertriage var 4.8 respektive 7.1%. Det förelåg ingen statistiskt påvisad skillnad.

Äldre patienter (>60 år) löper en ökad risk att undertriageras med både gamla och nya kriterier och det föreligger en trend att patienter utsatta för falltrauma har en ökad risk att undertriageras.
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My family: Louise, Ella, Agnes and Gunnar for endless love, encouragement and support. You are my pride and joy, I love you forever and now that I’m finished with my project you get to choose the next one. Is it the bathrooms?
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Appendix

The survey form in paper II
Dear Doctor,

All of the questions below relate to the hospital that you are currently working at.

1. In what country is your hospital located? (obligatorisk)

2. Please select below what kind of hospital you are currently working at:
   - University hospital
   - District hospital
   - Local hospital
   (obligatorisk)

3. Name of your hospital? * (obligatorisk)

   *This question will make it possible for us to see what hospitals that have given answers. Results will be compared on country and region level, hospital name will be anonymized

4. How many WBCTT (Whole-Body Computed Tomography for Trauma) do you estimate that your Radiology Department performs?
   - Fewer than 1 per week
   - 1 – 3 per week
   - 4 – 6 per week
   - About 1 per day
   - 1 – 3 per day
   - 4 – 6 per day
   - More than 6 per day

4. Does your Emergency Department / local ambulance service have an ‘alert’ policy for trauma patients?
   - Yes
   - No
   - Don’t know
5. Does your Emergency Department have a policy regarding the use of whole-body 
CT (also called major-trauma CT / pan-CT) for trauma patients?

☐ Yes – Departmental policy  Please go to question 7
☐ Yes – Trust-wide policy  Please go to question 7
☐ No - But use WBCT for trauma  Please go to question 6
☐ No  Please go to question 6
☐ Don’t know  Please go to question 6

6. Is your hospital currently in the process of defining guidelines for WBCT

☐ Yes  Please go to question
☐ No  Please go to question

7. What criteria are considered to decide which trauma patients undergo whole-body 
CT? (please tick as many as apply)

☐ Mechanism of injury
☐ Abnormal vital signs
☐ Anatomical site of injury
☐ Presence of multiple injuries
☐ Modified Early Warning Score (MEWS) or similar
☐ Other

If other, please specify ____________________________________________
__________________________________________________________________

10. If whole-body CT is deemed necessary, when is it usually performed?

☐ On patient’s arrival, before assessment
☐ As part of the primary survey
☐ After the primary survey
☐ As part of the secondary survey
☐ After the secondary survey
☐ Other

If other, please specify ____________________________________________
__________________________________________________________________
Before assessment = before first clinical examination
As part of the primary survey = During the first clinical examination
Secondary survey = Reexamination of the patient after the first clinical examination

8. **Who usually reports CT in-hours for trauma patients?**
   - Radiology consultant/attending
   - Radiology resident*
   - Either
   - Other

   * If other, please specify _________________________________________________

   * Resident = doctor training to become a specialist

9. **Who usually reports CT out-of-hours for trauma patients?**
   - Radiology consultant/attending
   - Radiology resident*
   - Either
   - Other

   * If other, please specify _________________________________________________

   * Resident = doctor training to become a specialist

10. **If the primary report is made by a resident, is the final report made by a radiology consultant/attending?**
   - Yes
   - No
   - Other, please specify

11. **How are results of the WBCTT-scan reported to the doctor in charge of the trauma? (please tick as many as apply)**
   - Orally
   - Written in trauma journal
12. The following six subquestions concern your WBCTT-protocol. Please tick the boxes below to describe how the images are visualized for each body-part.

a. Head
- Without contrast media
- Arterial phase
- Venous phase

b. Neck
- Without contrast media
- Arterial phase
- Venous phase

c. Thorax
- Without contrast media
- Arterial phase
- Venous phase

d. Upper abdomen
- Without contrast media
- Arterial phase
- Venous phase
- Excretory phase

e. Lower abdomen (incl. pelvis)
- Without contrast media
- Arterial phase
- Venous phase
- Excretory phase
f. Lower extremity
☐ This body-part is not included routinely
☐ Without contrast media
☐ Arterial phase
☐ Venous phase

13. How are the patient’s arms aligned when performing WBCTT?
☐ Above head if possible during the whole scan
☐ Parallel to the body during the whole scan
☐ Arms parallel to the body during scan of head and neck, arms above head when scanning thorax-abdomen
☐ On the patient’s chest
☐ Don’t know
☐ Other, please specify

14. Is the CT located adjacent* to or inside the emergency department?
☐ Yes, please describe:
☐ No
☐ No, but there are plans for relocating the CT closer to or inside the ED
* Adjacent= same floor and within 50 meters of trauma room.

15. Please specify the average total DLP (dose length product) measured in mGycm for the complete examination (WBCTT). If needed please consult the medical physicist at your hospital to help you answer this question.

16. Do you think there is a need for national/international WBCTT-guidelines?
☐ Yes
☐ No
Other: (free-text response)

17. Would your department be willing to adjust to guidelines for WBCTT including indications and CT scanning protocol?
☐ Yes
☐ No
Other: (Free-text response)

18. Any additional comments?

There are no further questions. Thank you for taking the time to complete this questionnaire.
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