Clinical Decision Rules and Their Use in the Management of Mild Traumatic Brain Injuries

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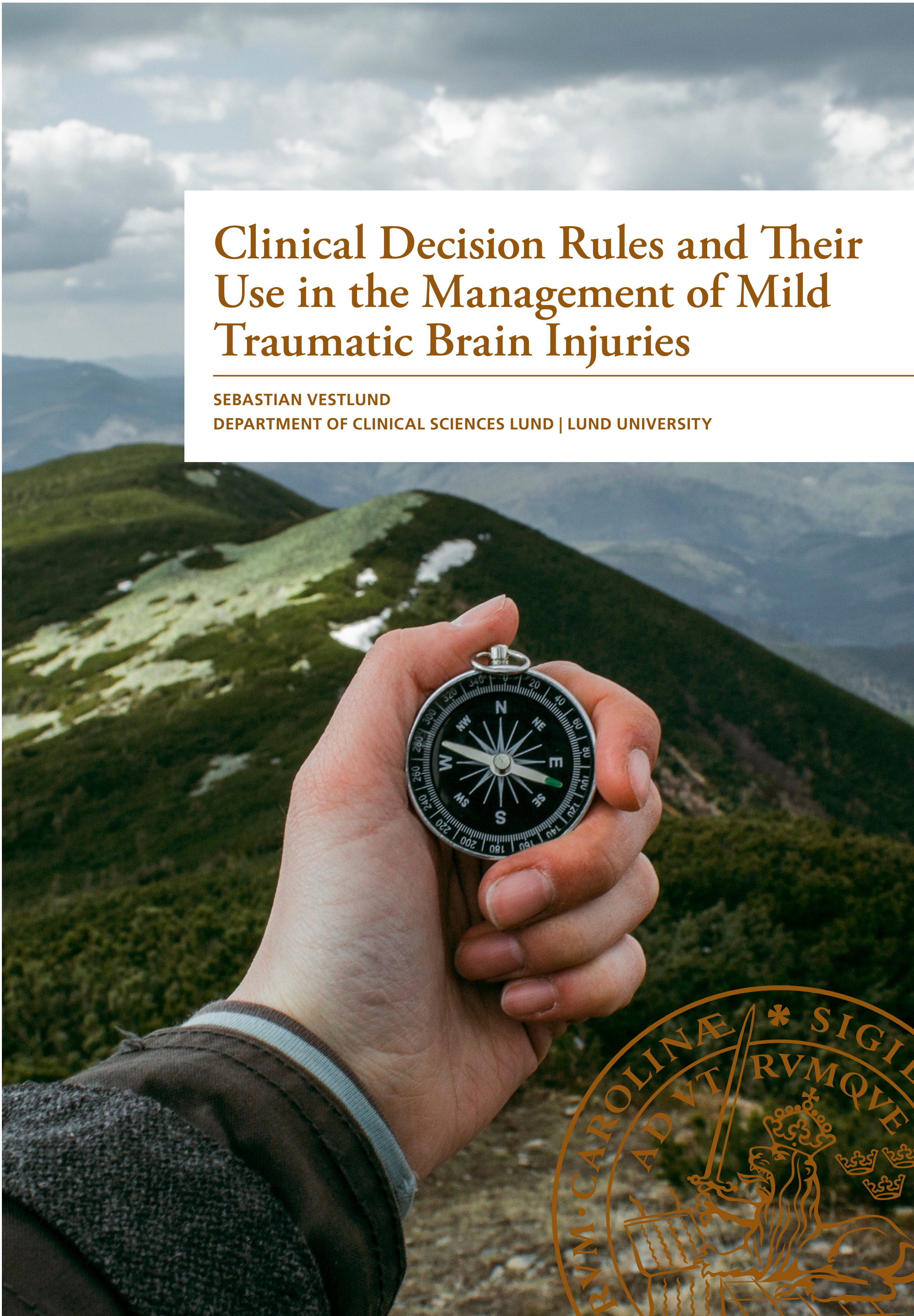

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DOCTORAL DISSERTATION

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Abstract

Background and aim: Clinical decision rules (CDRs) have been developed to facilitate management of patients with traumatic brain injuries(TBIs) and to reduce the rate of computerized tomographies (CT). However, guideline adherence is often low. Only a minority of patients with TBI have an intracranial injury (ICI), and even fewer will require an intervention. This dissertation aimed to describe the epidemiology of TBI patients, evaluate performance of five CDRs for managing these patients, evaluate performance of two CDRs for identifying patients with verified ICIs eligible for immediate discharge, and identify factors affecting guideline adherence, with particular emphasis on the local TBI guideline.

Methods: Paper I-III were conducted as retrospective reviews of medical records. In paper I, the epidemiology of head trauma patients was outlined, and factors associated with intracranial hemorrhage were identified. In paper II, five CDRs for TBI were compared and their performance and effect on CT rate were calculated. In paper III, two other CDRs were evaluated regarding their ability to identify patients with ICI eligible for immediate discharge. In paper IV, interviews with physicians were performed to identify factors affecting guideline adherence and to find areas of improvement in the local TBI guideline.

Results: Paper I: A shift in epidemiology to older patients suffering primarily from falls and several factors associated with intracranial hemorrhage were identified. Paper II: Adoption of either the Scandinavian Neurotrauma Committee CDR or the National Institute for Health and Care Excellence CDR could reduce the amount of CTs without missing injuries requiring intervention. Paper III: A small proportion of patients suffering mild TBI with a verified ICI could have safely been discharged. Paper IV: Barriers to guideline adherence were centered around low accessibility and flawed document design. Facilitators were centered around concise documents, good visual aids, high accessibility, and encouragement from colleagues

Conclusions: Median age of head trauma patients has increased. Adoption of certain CDRs could reduce CTs after mild TBIs. This could be done without missing injuries requiring intervention. It is possible to identify patients with ICI that can be discharged home safely. Guideline adherence can be improved, mainly through increased accessibility.

Key words: brain injury, traumatic, practice guidelines as topic, guideline adherence

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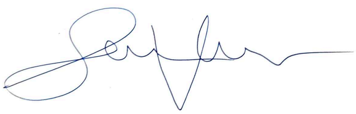
Signature  Date 2021-09-24

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“We learn something every day, and a lot of times it’s that what we learned the day before was wrong.”

-William E. Vaughan

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2. Svensson S, Vedin T, Clausen L, Larsson PA, Edelhamre M. *Application of NICE or SNC guidelines may reduce the need for computerized tomographies in patients with mild traumatic brain injury: a retrospective chart review and theoretical application of five guidelines*. Scand J Trauma Resusc Emerg Med. 2019 Nov 4;27(1):99.

3. Vestlund S, Vedin T, Tryggmo S, Larsson PA, Edelhamre M. *Performance of the Brain Injury Guidelines and the Mild Traumatic Brain Injury Risk Score in a Scandinavian population – A retrospective chart review of Traumatic Brain Injuries*. Submitted for publication.

4. Vestlund S, Vedin T, Edelhamre M, Lindén M, Larsson PA. *Ways to Improve Guideline Adherence in the Emergency Department – An Interview Study on the Management of Traumatic Brain Injuries.* Submitted for publication.

Populärvetenskaplig sammanfattning

Hjärnskador som uppstår efter våld mot huvudet är en vanlig anledning till besök på akutmottagningar i alla delar av världen och står för en betydande del av långvariga funktionsnedsättningar och dödsfall. Tidigare så var det framför allt unga män som drabbades, och då oftast genom olika sorters olyckor. Nu är det framför allt äldre, både kvinnor och män, som drabbas genom att de faller.

De flesta hjärnskador efter våld mot huvudet är av det så kallade milda, eller lätta, slaget och kallas i vardagligt tal för hjärnskakning. En mild traumatisk hjärnskada förutsätter att den som drabbats har haft en övergående störning i hjärnans funktion (exempelvis att tappa medvetandet, en kortare minnesförlust eller bli övergående förvirrad) men att hen sedan återhämtar sig i det närmaste fullständigt. De flesta som drabbas av en mild traumatisk hjärnskada kommer vara oskadda och återhämta sig fullständigt utan bekymmer, men ungefär var 15:e patient kommer ha någon form av hjärnblödning eller skallfraktur om man röntgar dem. Eftersom skallbenet är oeftergivligt så riskerar dessa blödningar att öka trycket innanför skallbenet, som kan vara skadligt och i värsta fall dödligt.

Dessa blödningar kan snabbt hittas med en skiktröntgen av hjärnan, men om alla med milda traumatiska hjärnskador ska genomgå skiktröntgen så hade det blivit väldigt många undersökningar eftersom det är en så vanlig skada. Många av undersökningarna hade dessutom inte påvisat någon skada och därmed utsatt den som drabbats för potentiellt farlig strålning i onödan.

Även om blödningarna kan vara farliga så har det genom forskning visat sig att de oftast inte är det, och bara en liten del av de med hjärnblödning efter mild traumatisk hjärnskada behöver opereras eller få annan behandling.

För läkarna på akutmottagningen som först träffar dessa patienter uppstår flera överväganden, dels vilka patienter som löper risk att ha en hjärnblödning (och som då behöver genomgå skiktröntgen), dels vilka av de med hjärnblödning som riskerar att behöva mer aktiv behandling. För att hjälpa läkarna i detta beslutsfattande så har flera beslutsstöd för att avgöra behov av skiktröntgen tagits fram på olika platser i världen. Dessa baserar sig på patientens sjukdomshistoria, omständigheter kring skadan och fynd vid undersökning på akutmottagningen, och har visat sig kunna minska antalet skiktröntgenundersökningar på ett säkert sätt.

Det har även på senare år tagits fram liknande beslutsstöd för att identifiera patienter med bekräftade hjärnblödningar som löper så låg risk för försämring att de skulle kunna skrivas hem i stället för att läggas in, men dessa är ännu inte etablerade i arbetet på akutmottagningar runt om i världen.

Ett problem är att många av de studier som ligger till grund för de mest använda beslutsstöden genomfördes för över 20 år sedan, och då var patienterna oftast yngre, friskare och hade andra typer av skademekanismer än idag. Det är därför inte säkert att dessa beslutsstöd presterar som de gjort tidigare, och för att ta reda på detta så måste den nuvarande patientgruppen först kartläggas närmare. Efter det så kan olika beslutsstöd testas mot varandra för att se vilka som på ett säkert sätt kan minimera antalet skiktröntgenundersökningar.

De beslutsstöd som tagits fram för att hitta patienter med hjärnblödningar som löper så liten risk att försämras att de kan skrivas hem direkt är få och nya, så nya att de aldrig har testats i Skandinavien tidigare. De verkar ha potential, men för att kunna börja användas inom sjukvården så måste de testas under kontrollerade former först.

Ett ytterligare problem är att beslutsstöd av det slag som beskrivits här sällan efterlevs fullt ut. En studie vid Helsingborgs lasarett kunde visa att de lokala riktlinjerna för behandling av huvudskador endast följdes i cirka 60% av fallen. Studien undersökte inte varför följsamheten var låg.

Denna avhandling ämnar bidra till att hitta lösningar på problemen ovan, och baserar sig på följande fyra delarbeten.

Delarbete 1 utgörs av genomgångar av sjukhusjournaler för patienter som sökte vård på akutmottagningen i Helsingborg efter huvudskada under 2013/2014. Här visade det sig att patienterna fortsätter att bli genomsnittligt äldre och att den huvudsakliga skademekanismen är fall i samma plan eller fall från låg höjd. Stigande ålder, att graden av den traumatiska hjärnskadan är mild, att skademekanismen är lågenergetisk och förekomst av nytillkomna neurologiska bortfall vid läkarundersökningen är förknippade med förekomst av hjärnblödning på skiktröntgen.

Delarbete 2 utgörs också av journalgenomgångar på samma patientgrupp, men denna gång under 2017. Här testas fem internationellt erkända beslutsstöd mot varandra för att se vilken av dem som skulle kunna minska antalet skiktröntgenundersökningar mest för patienter med milda traumatiska hjärnskador. Beslutsstödet från brittiska ”National Institute for Health and Care Excellence” och beslutsstödet från skandinaviska neurotraumakommittén kan båda minska antalet skiktröntgenundersökningar i denna grupp utan att någon patient som behövde någon särskild insats (ex. operation) skulle missas.

Delarbete 3 tittar på patienter med verifierade hjärnblödningar och/eller benbrott i skallen efter en huvudskada, också genom en journalgenomgång, för att se hur många patienter som kan skrivas hem direkt från akuten om någon av två internationella beslutsstöd utvecklade för detta hade använts. Båda beslutsstöden kunde hitta en liten grupp patienter som till synes hade kunnat skrivas hem direkt från akutmottagningen utan att löpa risk för bestående skador, men att andelen som kunde skickas hem är lägre än vad studierna tidigare visat.

Delarbete 4 bygger på ett antal intervjuer med läkare som arbetar eller har arbetat på akutmottagningen i Helsingborg, med syftet att utforska vad som påverkar och upplevs påverka följsamhet till riktlinjer på akutmottagningen och även vad som kan bli bättre i den lokala riktlinjen för huvudskador. Faktorer som upplevs bidra till minskad riktlinjeanvändning handlar om dålig tillgänglighet på riktlinjer och en bristfällig utformning av själva riktlinjedokumenten. Faktorer som i stället upplevs öka användandet är att dokumenten är koncisa, använder sig av väldesignade bilder, är lättillgängliga och att användande uppmuntras av kollegor och chefer. Den lokala riktlinjen för huvudskador är över lag bra, men vissa delar upplevs som överdrivet försiktiga och vissa upplevde att vissa patientgrupper utelämnas från riktlinjen.

Avhandlingens slutsatser är följande:

- Patienter med huvudskador är äldre och den huvudsakliga skademekanismen är fall. Hög ålder, mild traumatisk hjärnskada, nytillkomna neurologiska avvikelser och lågenergetisk skademekanism är förknippat med hjärnblödningar i denna grupp.

- Användande av vissa beslutsstöd kan minska behovet av skiktröntgen efter huvudskada.

- Beslutsstöd kan möjligen minska behovet av sjukhusvård efter mild traumatisk hjärnskada, även om röntgen visar en hjärnblödning.

- Det finns många faktorer som upplevs påverka följsamhet till riktlinjer på akutmottagningen, där det viktigaste var att riktlinjerna var lättillgängliga och utformande på ett lättförståeligt sätt.

Abbreviations

BIG = Brain Injury Guidelines

CCHR = Canadian CT Head Rule

CDR = Clinical Decision Rule

CT = Computerized Tomography

ED = Emergency Department

GCS = Glasgow Coma Scale

ICI = Intracranial Injury

ICU = Intensive Care Unit

IQR = Interquartile Range

mTBI = Mild Traumatic Brain Injury

mTBI-RS = Mild Traumatic Brain Injury Risk Score

NEXUS II = National Emergency X-Radiography Utilization Study II

NICE = National Institute for Health and Care Excellence

NOC = New Orleans Criteria

RLS-85 = Reaction Level Scale 85

S100B = S100 calcium-binding protein B

SDI = Socio-demographic Index

SNC = Scandinavian Neurotrauma Committee

TBI = Traumatic Brain Injury

WHO = World Health Organization

Introduction

General introduction to traumatic brain injuries

Traumatic brain injury (TBI) is a common reason to seek medical attention worldwide and a significant cause of mortality, morbidity, and an economic burden for society(1–4). Improving the care for these patients is essential to reduce adverse outcomes and utilize healthcare resources more effectively.

Definition of TBI and mTBI

Traumatic brain injury is an acquired brain injury resulting in either altered brain function or other evidence of brain pathology caused by an external physical force(5). It can be caused by the head being struck by a moving object, the head striking a stationary object, or a foreign object penetrating the skull (e.g., bullet).

Traumatic brain injuries are often classified as either mild, moderate, or severe depending on the patient's Glasgow Coma Scale (GCS) score upon presentation. Depending on the patient's best eye, verbal and motor response, the patient is assigned a score between 3-15(6). Mild injury corresponds to a GCS-score of 13-15, a moderate injury corresponds to a GCS-score of 9-12, and a severe injury corresponds to a GCS-score of 3-8. In some instances, another grade is used - minimal TBI. A minimal TBI is defined as a GCS of 15 and no presence of loss of consciousness or amnesia(7).

The mild traumatic brain injury (mTBI) category is the largest, constituting between 71-97.5% of the total cohort(8,9). Mild traumatic brain injury has further been defined by the American Congress of Rehabilitation Medicine in 1993 and then slightly modified by the World Health Organization (WHO) collaborating center task force on mild traumatic brain injury. The definition of mTBI by the American Congress of Rehabilitation Medicine is as follows:

> “A patient with mild traumatic brain injury is a person who has had a traumatically induced physiological disruption of brain function, as manifested by at least one of the following:

1. any period of loss of consciousness.
2. any loss of memory for events immediately before or after the accident;
3. any alteration in mental state at the time of the accident (e.g., feeling dazed, disoriented, or confused); and
4. focal neurological deficit(s) that may or may not be transient, but where the severity of the injury does not exceed the following:

   • loss of consciousness of approximately 30 minutes or less
   • after 30 minutes, an initial GCS of 13–15; and
   • posttraumatic amnesia not greater than 24 hours."

The WHO collaborating center task force on mild traumatic brain injury includes the possibility to determine the GCS score upon the first presentation and not just within 30 minutes. They specify that the manifestations of mTBI cannot be caused by other injuries, their treatment, intake of psychoactive substances, other problems (psychological trauma, language barriers, or coexisting medical conditions), or penetrating trauma(10,11). The term "concussion" is often used to describe an mTBI. Despite these attempts at defining mTBI, no uniform definition exists.

Another instrument for measuring the level of consciousness is the Reaction Level Scale 85 (RLS-85). It was developed in Sweden in the 1980s and consists of an eight-grade scale, ranging from 1 (totally alert) to 8 (comatose with no motor response to pain). A score of 1-3 denotes a conscious patient with increasing levels of lethargy/confusion, and a score of 4-8 denotes an unconscious patient with increasingly worse degrees of motor response upon pain stimulation (4 = Localizes pain, 5 = Withdraws from pain, 6 = Flexion to pain, 7 = Extension to pain and 8 = No response) (12).

Epidemiology of TBI and mTBI

Globally

The incidence and epidemiology of TBI vary significantly around the world. The true incidence of TBI is very hard to determine since many patients (25%) either do not seek medical attention for their TBI or are treated as outpatients in either the emergency department (ED) or at their primary care physician(13).

The Global Burden of Disease study measured the global, regional, and national burden of TBI in 2016 by measuring incidence and prevalence through inpatient and outpatient records, literature studies, and survey data. The global annual incidence was estimated to be 27.08 million cases, with an age-standardized incidence of 369/100,000. The countries were stratified according to the Socio-demographic

Index (SDI), a composite indicator of the development of a country based on fertility rate, education level, and individual income. The incidence was highest in middle-high SDI countries and increased globally by 3.6% since 1990, with a significant increase in middle SDI countries balanced by a modest decrease in high- and low-SDI countries. The most common cause, regardless of the country's SDI level, was falls followed by motor vehicle accidents. The reduction in incidence in high SDI countries was attributed to improved road safety regulations (1,14)

A study by Dewan et al. estimated the annual incidence of TBI to 69 million, significantly higher than the Global Burden of Disease study. They used open-source traffic injury data and estimated the total TBI incidence. They did this based on the relative contribution of road traffic collisions to the total TBI burden in different WHO regions and income groups. The total burden of TBI was three times greater in low- to middle-income countries when compared to high-income countries. The most common mechanism of injury in lower-income countries was road traffic collisions (56%), which was significantly higher when compared to high-income countries (25%)(2).

Europe

Several systematic reviews regarding the epidemiology of TBI in Europe have been conducted in the last decades. A systematic review conducted in 2006 by Tagliaferri et al. included studies from different countries in Europe between 1988 and 2005. The included studies were on different TBI populations, were not standardized, and were often difficult to compare. This review showed a wide incidence rate for TBI with a mean value of 243/100,000 annually. The mortality rate was also very variable, with a mean value of 15/100,000. The vast majority of head injuries were mild (79%). The majority of patients were male, and the most common mechanism of injury was motor vehicle accidents closely followed by falls(15).

A decade later, subsequent reviews showed slightly contradicting findings regarding incidence, where Peeters et al. found a possible increase in overall incidence while Brazinova et al. showed stable incidence. Several of the included studies in the review by Peeters et al. showed an increasing mean age and an incidence peak in higher ages than previously reported. Men continued to be over-represented, and the trauma mechanism shifted from predominantly motor vehicle accidents to predominantly falls. A study with data from 2012 by Majdan et al. using statistics from the Eurostat database about the hospital-based incidence of TBI from 24 European countries yielded a pooled discharge rate of 287/100,000 and a mortality rate of 11.7/100,000 due to TBI. By extrapolating these numbers, an estimated 82,000 fatalities and 2.1 million hospital discharges occurred in Europe the same year. This trend of increasing age and transition from motor vehicle accidents to falls was previously brought forward by Roozenbeek et al. in 2013 (8,16–19).

Scandinavia

The incidence of TBI in Scandinavian countries has been estimated on several occasions in the last three decades. Changing trends regarding overall incidence, age-specific incidence, trauma mechanism, and rate of hospitalization following TBI have been observed in some studies. In contrast, other studies show other aspects that are more constant over time.

Small studies from single institutions in Sweden conducted between 1991 and 2007 show an incidence of TBI between 249-546/100,000. However, the lower incidence figure only accounts for hospital admissions. In these studies, the largest group consisted of young males. A study from Pedersen et al. evaluated the epidemiology of TBI in Sweden between 1987-2010 using the Swedish Hospital Discharge Register that showed an overall decreasing incidence of hospital admissions for TBI, especially for concussion. At the same time, an increase in hospital admissions for subdural hemorrhage and subarachnoid hemorrhage was seen and an increased hospitalization incidence for patients over 85 years of age. Among patients transferred to a neurosurgical facility between 1992-2001, the incidence and proportions of injury severity were relatively constant(20–24).

Multiple single-center studies from Sweden and Norway and nationwide studies from Finland, Sweden, Denmark, Norway, and Iceland conducted in the last three decades show a higher proportion of males suffering TBI, approximately 55-75%. Falls from different heights, primarily ground-level and low-elevation, constitute the most frequent trauma mechanism and account for the absolute majority of the cases in all but one study by Skandsen et al. (2018) where patients over 60 were excluded. The proportion of falls has remained constant or increased, especially in the elderly, while the proportion of motor vehicle accidents has decreased. The included studies paint a nuanced picture regarding overall TBI incidence, where the hospitalization rate after TBI has decreased in Sweden and Denmark over time while increasing in Finland. Several studies find an increased incidence of TBI-related hospitalizations of any severity in the elderly, even though the total incidence is decreasing or constant (19-33)

Management of patients with mTBI in the ED

Patients with mTBI are at risk of suffering from a wide range of intracranial injuries with the potential for both morbidity and mortality. These include, but are not limited to, different kinds of intracranial hemorrhages, diffuse axonal injury, vault of skull fractures, and basal skull fractures. These injuries are present in 6.4-8.2%

of patients with mTBI, and 3.6-9.2% of these patients will require surgical intervention(35–37).

These injuries are identified through different imaging modalities, computerized tomography (CT) or magnetic resonance imaging. A CT is generally preferred in the acute setting because it is readily available, quickly acquires the desired images, and identifies injuries potentially needing urgent intervention. Magnetic resonance imaging is more sensitive for minor hemorrhages, white matter shear injury, and older hemorrhages where the blood changes composition but is less sensitive to bony injuries.

Magnetic resonance imaging is also not readily available around the clock and takes relatively longer to perform than CT, which can be problematic in uncooperative or agitated patients(38–42).

Access to CT has steadily increased since its introduction. It has been liberally used in managing a patient with mTBI, potentially influenced by several retrospective studies from the early nineties showing large proportions (17.2-18%) of mTBI-patients with intracranial injuries(43–45). These proportions were contradicted by other prospective studies, showing much lower incidences in the range of 6.1-9.4%(37,46,47).

Clinical decision rules for TBI

Several clinical decision rules (CDRs) have been developed to use CT-scanning more judiciously for patients with mTBI. These CDRs aim to identify patients at a higher risk for intracranial injury (ICI) and indicate when a CT should be performed through patient history, patient characteristics, clinical findings, and sometimes laboratory assays of biomarkers. Some of these guidelines are locally derived, not receiving significant spread outside the institution, and some are widely spread around the world and have had their performance externally validated(48). The guidelines most relevant for this dissertation can be seen below.

The Canadian CT Head Rule

The most widely used and studied guideline is the Canadian CT Head Rule (CCHR), developed in 2001. The CCHR applies to patients with a GCS-score of 13-15 and a history of witnessed loss of consciousness, definite amnesia, or witnessed disorientation following head trauma. The CCHR stratifies patients as either high risk (for neurological intervention) or medium risk (for brain injury on CT) based on patient characteristics, history, clinical findings, and trauma mechanism. Suppose a patient satisfies at least one high-risk criterion (GCS <15 at two hours post-injury, suspected open/depressed skull fracture, signs of basal skull fracture, two or more episodes of vomiting, or age ≥ 65), a CT is mandatory. If the patient satisfies either one of the two medium risk criteria (amnesia before the injury > 30 minutes or met criteria for dangerous mechanism), either CT or close observation is warranted. A dangerous mechanism was defined as either a pedestrian struck by a motor vehicle, occupant ejected from a motor vehicle, or a fall from greater than 3 feet/five flights of stairs.

In the original study, the CCHR showed a 98.4% sensitivity and a 49.6% specificity for clinically important brain injury and a 100% sensitivity and 68.7% specificity for neurological intervention(49).

The CCHR has since its development been extensively externally validated in Canada, the United States of America, Europe, and Asia. When externally validated, CCHR had a sensitivity of 79.2-100%, a specificity of 36.3-65% for ICI, a sensitivity of 88.9-100%, and a specificity of 37.2-80% for neurological intervention(50–56).

The New Orleans Criteria

The New Orleans Criteria (NOC) were developed in 2000 based on patient characteristics, history, and examination findings, albeit slightly different from the CCHR. The NOC are applicable when the patient has had a transient loss of consciousness, has a normal neurological examination, and has a GCS of 15. If a patient then has one or more of the following findings – headache, vomiting, age > 60 years, intoxication, a deficit in short-term memory, history of seizure after the injury, or physical evidence of trauma above the clavicles – a CT scan should be performed to rule out ICI. In the original study, the NOC acquired 100% sensitivity and 25% specificity for any ICI, potentially reducing their use of CT by 22%(36).

The NOC and the CCHR have been compared to each other in several studies. The NOC trend towards higher sensitivity and reduced specificity for ICI detection (50–57).

The National Emergency X-Radiography Utilization Study II guidelines

The National Emergency X-Radiography Utilization Study II (NEXUS II) was a multicentre, prospective study conducted in the United States of America in the early 2000s and published in 2005. The NEXUS II guidelines apply to all patients suffering head trauma, not requiring the loss of consciousness, amnesia, or witnessed disorientation compared to the CCHR or the NOC. The NEXUS II guidelines state that CT should be ordered if the patient satisfies one or more of the following criteria: evidence of significant skull fracture, scalp hematoma, neurologic deficit, abnormal level of alertness, abnormal behavior, coagulopathy, persistent vomiting, or age ≥ 65 years. Abnormal level of alertness was defined by several different findings, including but not limited to a GCS of 14 or less: delayed or inappropriate response to external stimuli; excessive somnolence; disorientation; impaired short-term memory when tested and perseverating speech. Abnormal behavior was defined as any inappropriate action displayed by the patient (e.g., inconsolable, excessive agitation, or lack of affective response).

The NEXUS II guidelines achieved a sensitivity of 98.3% and a specificity of 13.7% for clinically important ICI and only included patients who underwent a CT (85.2% of the total cohort). The NEXUS II guidelines failed to identify 16 patients with clinically important ICI, one of which required immediate neurosurgical intervention(58).

A prospective validation study was conducted in the United States of America between April 2006 and December 2015, including 11,770 patients suffering blunt trauma to the head. It showed a 100% sensitivity and a 24.9% specificity for neurosurgical intervention and a 99% sensitivity and 25.6% specificity for clinically important ICI. In a subgroup of this cohort, the NEXUS II guidelines were compared to the CCHR. The NEXUS II guidelines outperformed the CCHR regarding detecting patients requiring neurosurgical intervention and specificity for patients with significant ICI but lower sensitivity. Another prospective validation study comparing the CCHR, the NOC, and the NEXUS II, performed at several EDs in Korea and Singapore, showed superior sensitivity and specificity for clinically important ICI, superior specificity for the need of neurosurgical intervention but lower sensitivity(51,59).

The National Institute for Health and Care Excellence guidelines

The National Institute for Health and Care Excellence (NICE) in the United Kingdom provides national guidelines for managing various medical conditions. They have since 2003 provided a continuously updated, national guideline on the management of TBI, with the latest version published in 2014. This guideline was developed through systematic reviews of the best available evidence, explicitly considering cost-effectiveness. The NICE guidelines specify that a CT should be performed within one hour of presentation if the patient fulfills at least one of the following criteria:

- GCS <13 on initial assessment,
- GCS <15 at 2 hours after injury,
- Suspected open/depressed skull fracture,

- Any sign of basal skull fracture,
- Post-traumatic seizure,
- Focal neurologic deficit or,
- More than one episode of vomiting.

If the patient does not fulfill any of these criteria, but at least one of the following, a CT should be performed within eight hours of presentation – Age >65 years, history of bleeding/clotting disorder, dangerous mechanism, or more than 30 minutes of retrograde amnesia before the injury. CT should be performed within eight hours in patients treated with an anticoagulant even if the patient does not satisfy any previous criteria(60).

The NICE guidelines have shown varying levels of sensitivity for ICI overall (72.5-99%) and the subset of ICI requiring neurosurgical intervention (94.1-94.4%), but generally with high specificities (31-70% and 43-46.1% respectively)(50,55,61,62). It is worth noticing that only one of these studies examined the latest versions of the NICE guideline. The others examined the original 2003 guideline(55).

The Scandinavian Neurotrauma Committee guidelines

The Scandinavian Neurotrauma Committee (SNC) was founded in 1998 after an initiative from the Scandinavian Neurosurgical Society and has since then published several guidelines on the management of TBI of different severities. The committee consists primarily of neurosurgeons and anesthesiologists working in Sweden, Norway, Denmark, and Finland (63).

The committee has published management guidelines for managing minimal, mild, and moderate TBI in 2000 and updated these guidelines in 2013. They have since then published a guideline for the management of minimal, mild, and moderate TBI in children(64–66).

The latest edition of their guideline regarding moderate, mild, and minimal TBI aimed to identify which patients required CT and which patients required admission/repeat CT. The guideline was intended to apply to the entire spectrum of patients managed at the ED after minimal, mild, or moderate TBI. The guideline was developed according to the Appraisal of Guidelines, Research and Evaluation (AGREE II) instrument. The AGREE II instrument consists of items that should be addressed to ensure correct methodology when creating and presenting a guideline. Each recommendation's summarized quality of evidence was graded from high quality to very low quality per the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system. The GRADE system is a framework for grading the quality of evidence and the strength of recommendations for diagnostic tests. A draft for the updated guideline was constructed and refined using a modified Delphi process, field testing, and input from other medical specialties involved in the care of TBI patients(67–69).

A flowchart from the latest SNC guideline can be seen in figure 1, presenting a stepwise approach to managing TBI patients.

Figure 1:
Flowchart for the management of TBI from Undén et al. (2013). Reprinted with permission from Johan Undén

The SNC guideline was the first to introduce a brain biomarker into clinical practice, S100 calcium-binding protein B (S100B). It is a small protein mainly found in astrocytes and, to a lesser extent, chondrocytes, adipocytes, malignant melanoma cells, and Schwann cells. It is secreted from astrocytes in response to insults and transported to the bloodstream through the cerebrospinal fluid, readily available for analysis through venous sampling. S100B has shown a negative predictive value of 99% and a 97% sensitivity for detecting traumatic brain pathology visible on CT, but with a specificity of only around 30%(70,71).

The guideline has been validated in two Scandinavian cohorts and a north American cohort. The sensitivity and specificity for ICI were 94-97% and 19-34%, respectively. Neither of the patients that were missed by the guideline required neurosurgical intervention. The guideline in full context could potentially reduce the CT rate in the North American cohort by 32%, and the introduction of S100B could potentially reduce the CT rate by 9-14.8% in the Scandinavian cohorts (72–74).

Management of patients with mTBI and intracranial injury

Patients with a traumatic ICI are regularly admitted to the hospital for observation and a neurosurgical consult is obtained. Sometimes a repeat CT is performed to monitor the status of the hemorrhage(75,76).

A growing body of evidence from the last decades suggests that patients with mTBI and an ICI might require less rigorous monitoring, less routine repeat head CT scans, and less mandatory neurosurgical consultation than what is often performed currently (75,77–83).

The need to identify patients at a higher risk of deterioration is of critical importance since a delay in treatment can have severe consequences. At the same time, identifying patients that are at minimal risk for deterioration is also important since these patients can be managed with less rigorous monitoring or even be discharged directly from the ED. The risk of deterioration or need for neurosurgical intervention is associated with the ICI type and severity, GCS level, and age. An epidural hematoma, midline shift/mass effect, a lower initial GCS, and a higher age have been associated with deterioration and the need for neurosurgical intervention. Subarachnoid hemorrhage has been associated with a lower risk for deterioration and neurosurgical intervention(84–87).

Two CDRs have been developed to stratify deterioration risk and the need for neurosurgical intervention, the Brain Injury Guidelines (BIG) and the Mild Traumatic Brain Injury Risk Score (mTBI-RS).

The BIG were developed by Joseph et al. in the United States in 2013, categorizing mTBI-patients with verified ICI into one of three categories (BIG 1-3) based on previous medical history, clinical findings, and radiological findings. Patients categorized as BIG 1 were observed for 6 hours in the ED and discharged if no deterioration occurred. BIG 2-patients were admitted but not subjected to a repeat head CT or neurosurgical consultation. BIG 3-patients were admitted and went through a repeat head CT, and a neurosurgical consultation was obtained. Meeting just one criterion for either BIG 2 or BIG 3 immediately upgraded the patient to that category. In order to be classified as BIG 1, all of the following criteria had to be met:

- Normal neurological examination,
- Not intoxicated,
- No treatment with anticoagulation or platelet inhibitors,
- No skull fractures,
- If subdural or epidural hematoma, less than 5 mm thick,
- If parenchymal hemorrhage, less than 5 mm thick in a single location,
- If subarachnoid hemorrhage, only trace amounts and,
- No presence of intraventricular hemorrhage.

In the original study, 121 (9.8%) patients could be categorized as BIG 1 and thus discharged directly from the ED. No patient in the BIG 1 group had worsening findings on repeat head CT-scan or deteriorated. A validation study conducted by the original authors at the original study site compared patients classified as BIG 1 managed by acute care surgeons and compared it to patients in the same category where neurosurgery was consulted. No patient deteriorated, required neurosurgery, or died in any group. An external validation, evaluating the BIG retrospectively and a modified BIG prospectively, classified 14.9% of the patients as BIG 1 with zero patients with neurological decline, progress on repeat head CT or requiring intervention(88–90).

The mTBI-RS was developed by Marincowitz et al. in England in 2020. Unlike the BIG, mTBI-RS is a score-based CDR, assigning different scores depending on the presence of different risk factors for intracranial hemorrhage, status findings, and injury severity grade on CT. A score of zero has to be achieved to be eligible for discharge. Patients at the cut-off of zero have the following characteristics:

- Initial GCS of 15,
- A single simple skull fracture or hemorrhage less than 5 mm,
- Up to two extracranial bony or organ injuries not requiring hospital admission,
- Not taking anticoagulants or platelet inhibitors,
- No cerebellar/brainstem injury and,
- A normal neurological examination.

In the original study, the mTBI-RS would theoretically have been able to discharge 87/1569 (5.5%) with a sensitivity and specificity of 99.5% and 7.4%, respectively, for deterioration within 30 days. The outcome was defined as death due to TBI, neurosurgery, seizure, a drop in GCS by at least one point, ICU-admission due to TBI, intubation, or readmission due to TBI. None of the patients that deteriorated required any active intervention or died (a drop in GCS and seizure). BIG was tested in this cohort and could discharge 57/1569 (3.6%) with a sensitivity and specificity of 99.5% and 4.8%, respectively. One patient that BIG missed went on to require intubation(91).

The mTBI-RS (by the authors named Hull Salford Cambridge Decision Rule) and BIG have been externally validated using data from the Center-TBI study. This study included 4509 TBI patients of all severity grades across 63 centers in Europe and Israel, prospectively collected between December 2014 and December 2017. One thousand forty-seven patients were eligible for comparison between mTBI-RS and BIG. The outcome was the same as in the mTBI-RS derivation study. The mTBI-RS acquired 100% sensitivity and 4.7% specificity. BIG acquired 94.6% sensitivity and 13.3% specificity(92,93).

Guideline adherence in the ED

Guideline adherence in the ED varies depending on condition, type of guideline, and organizational factors(94). Cabana et al. investigated barriers for guideline adherence and identified several internal and external barriers. Internal barriers include:

- lack of awareness (not knowing a guideline exists),
- lack of familiarity (not knowing how to interpret or apply a guideline),
- lack of agreement (not agreeing with a guideline recommendation),
- lack of self-efficacy (not believing that oneself can adhere to a guideline),
- lack of outcome expectancy (not believing that adhering to a specific guideline will improve outcome) and,
- the inertia of previous practice.

External barriers were divided between guideline-related barriers (hard to use, inconvenient, or eliminating an established behavior), patient-related barriers (inability to integrate guideline recommendations with patient preferences), and environmental-related barriers (unavailability of specific competencies, facilities, or resources outside the physician's control)(95)

Successful guideline implementation depends on multiple factors. Wollersheim et al. stresses that implementation should be considered from the start of development through

> "…attention to the relevance of the topic, credibility (systematic development by rigorous, transparent methodology), involvement of all relevant stakeholders and attention to the impact on resources, materials and facilities, accessibility and an attractive design and tools for application and monitoring in practice. To integrate guidelines into normal care processes, they should be incorporated in local care protocols, disease management programmes, and clinical pathways"(96).

De Wit et al. produced a list in 2018 of recommendations for implementing new scientific evidence in the emergency department through a systematic review and a questionnaire survey conducted with members of the Canadian Association of Emergency Physicians experienced in ED implementation. It emphasized the following points:

- Importance of anchoring an implementation decision with the group for whom it is intended before the start,
- Adopt novel findings after sufficient validation,
- Focus on specific areas where care can be significantly improved,
- Develop implementation strategies that address local circumstances,
- Implementation on multiple levels,
- Involvement of all relevant stakeholders,
- Tracking compliance/outcome with the intervention,
- Having a business plan for sustaining the implemented change,
- Conduction of formal ED implementation studies and
- Registration of these implementation studies in an appropriate trial database to minimize bias(97).

Aims of the dissertation

The general aim of the dissertation was to provide a scientific foundation for improving the management of patients seeking medical attention at an ED after an mTBI through better use of CDRs.

The specific aims of this thesis were:

- To evaluate characteristics and epidemiology of adults presenting with the chief complaint of head trauma to identify clinical features predicting intracranial hemorrhage.

- To determine the performance of CCHR, NOC, NEXUS II, NICE, and SNC guidelines for managing mTBI and their respective ability to reduce the amount of CT-scanning safely.

- To determine if it would be possible to safely discharge certain patients with ICI after mTBI directly from the emergency department using either the mTBI-RS or the BIG in a Swedish setting.

- To explore factors that affect guideline adherence in the ED and what changes can be made to our existing CDR for mTBI to improve it.

Methods & Statistics

Setting

The study populations in paper I-II consists of patients seeking care at the ED at Helsingborg hospital in 2013/2014 and 2017, respectively. The study population in paper III consisted of patients with verified ICI initially treated at Helsingborg hospital between 2014 and 2019. Paper IV was aimed towards physicians of various experience levels who had worked in the ED section that managed TBI patients at Helsingborg hospital for at least four weeks.

Helsingborg hospital is a secondary care hospital located in Helsingborg, Sweden. It serves a population of approximately 250,000 and has around 60,000 ED visits each year. The ED is staffed with resident physicians in emergency medicine, general surgery, internal medicine, and general interns around the clock. The hospital has access to a general intensive care unit (ICU). The closest hospital with a neurosurgical service and neurointensive care unit is located 55 km away at the Skåne University Hospital in Lund. Electronic health records are utilized. The ED uses the program Melior by Cerner Corporation, and notes from all hospital departments and notes from other hospitals in the region can be viewed by physicians in the ED.

The hospital provides locally adapted guidelines regarding the workup and treatment of various clinical conditions through the local intranet or a locally produced guideline pamphlet. The current guideline regarding the initial management of TBI is a local adaption of the latest SNC guideline(65).

Paper I

A retrospective review of medical records was performed to evaluate the current epidemiological features of patients seeking care for head trauma and identify signs and symptoms associated with intracranial hemorrhage. The review included patients 18 and older presenting to the ED at Helsingborg hospital who got registered in the electronic patient registry as “head trauma” between November

11th, 2013 and November 30th, 2014 (384 days). Patients suffering multi-trauma were managed according to ATLS™ and excluded from the analysis.

The following parameters were manually extracted from the medical records regarding the initial visit to the ED and the possible subsequent admission:

1. Age
2. Gender
3. Head CT performed
4. Head CT outcome
5. Admission to a general hospital ward
6. Admission to ICU
7. Admission to neuro-ICU
8. Neurosurgical intervention
9. Degree of head injury
10. Level of consciousness RLS-85
11. Level of consciousness GCS
12. Blood pressure
13. Pulse rate
14. Size of pupils
15. Bodyweight
16. Height
17. Past medical history
18. Anticoagulant treatment
19. Platelet inhibitor treatment
20. Other medication
21. Focal neurological deficits
22. Neurological deterioration during observation
23. S100B level
24. Nausea
25. Vomiting

26. Number of vomits
27. Amnesia - type and duration
28. Loss of consciousness
29. Peritraumatic seizure
30. Posttraumatic headache
31. Worsening headache
32. Trauma energy level
33. Clinical signs of basal skull fracture
34. Orthostatic hypotension preceding injury
35. Cardiac dysrhythmia preceding injury
36. Time from injury to medical examination at the emergency department
37. Intoxication

Statistics

Epidemiological features of the cohort were presented as medians when skewed. Q-Q plots and the Shapiro-Wilks test were used to test for normal distribution. Missing data were imputed using the series median.

A post hoc analysis with multiple binominal logistic regression was performed to identify factors associated with intracranial hemorrhage. A stepwise regression analysis was made, starting with a simple binomial logistic regression to identify significant parameters ($p < 0.4$), which was then entered into a multiple regression model. A subsequent multiple regression was performed, using significant parameters ($p < 0.05$) from the first multiple regression analysis to yield parameters independently associated with intracranial hemorrhage. All statistical analyses were performed on IBM SPSS ® Statistics for Macintosh, version 21.0.

Paper II

A retrospective review of medical records was performed in adult patients presenting to the ED at Helsingborg hospital after a head injury between the 1st of January 2017 and the 31st of December 2017. The aim was to evaluate the performance of the CCHR, NOC, NEXUS II, NICE, and SNC guidelines. Patients were identified through the electronic ED registry. Inclusion and exclusion criteria can be seen in figure 2.

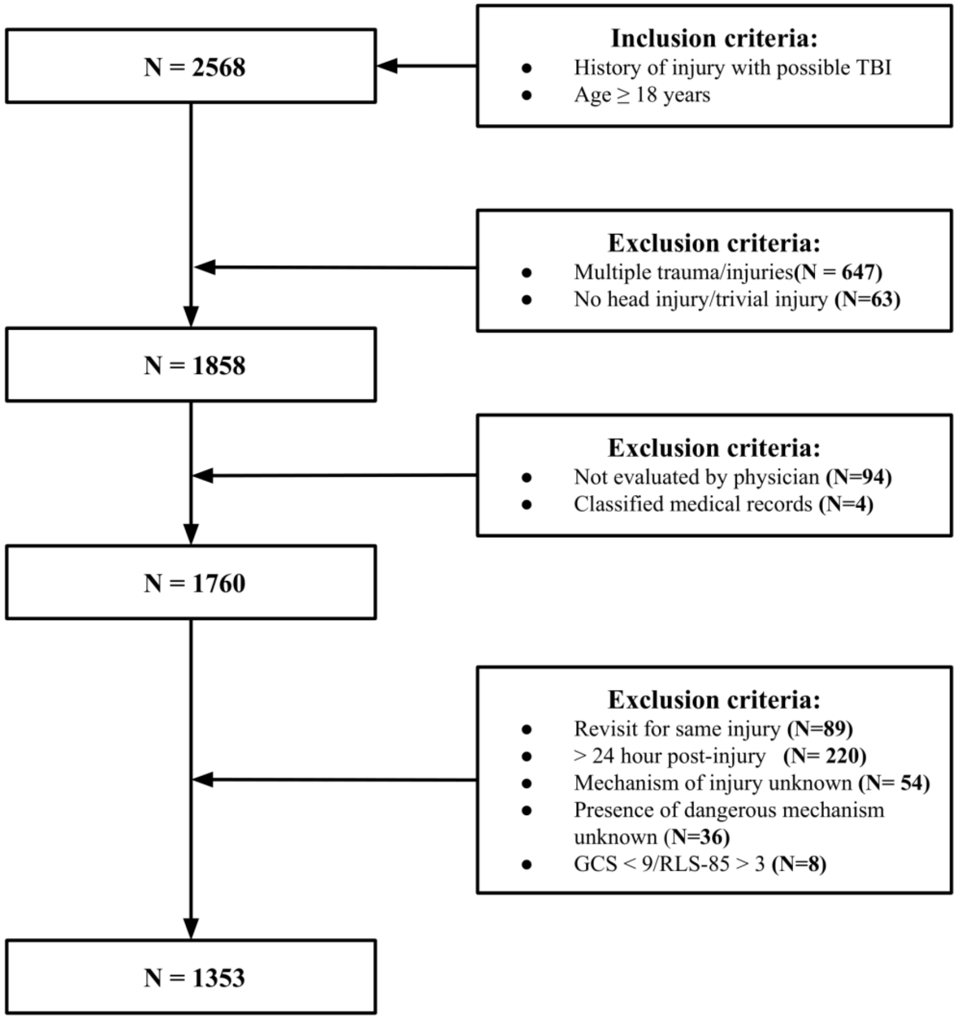

Figure 2:
Inclusion and exclusion criteria for paper II

The parameters collected in paper I were also collected in this paper, with additional parameters needed for determining the outcome of each CDR for each patient. The additional parameters were the following:

1. Presence of abnormal behavior as defined by Mower et al. (98).
2. Abnormal level of alertness as defined by Mower et al. (98).
3. Presence of dangerous mechanism as defined by Stiell et al. (49).

4. Clinical signs of depressed skull fracture.
5. Presence of a scalp hematoma.
6. Signs of trauma above the clavicles.
7. Presence of an intraventricular shunt.
8. Presence of skull fracture on CT (if performed).
9. Presence of other radiological examinations that were performed in the ED.
10. Endotracheal intubation during the current admission.
11. Death due to ICI during the current hospital stay.

The review included notes from the current ED visit, lab results, radiology reports, and, in select cases, previous notes from up to a year before the check for medications and comorbidities. If the patient was admitted, notes from the subsequent admission were reviewed as well. Missing data from the physicians' notes were filled in using notes from medical personnel other than the treating physician, primarily nurses. If no written information regarding the previous medical history or a clinical finding, it was assumed to be absent.

To enable analysis and comparison of the guidelines, some assumptions and conversions were made.

- GCS-level was interpreted from RLS-85 when no formal documentation of GCS-level was available. An RLS-85 score of 1 was equated to GCS 15, RLS-85 2 was equated to GCS 14, and RLS-85 3 was equated to GCS 9-13(65,99,100).

- The level of consciousness was retrieved once, approximately 10-60 minutes after arrival to the ED. Where no physician note could be found, the note from the triage nurse was used.

- Treatment with direct oral anticoagulants and low-molecular-weight heparin of any dosage was equated with warfarin treatment.

- Any amnesia was considered a deficit in short-term memory.

- Any amnesia > 30 minutes was deemed a risk factor for CCHR and NICE.

- If the SNC guideline recommended S100B analysis but none was performed, it was interpreted as an indication for CT.

- When analyzing the SNC guideline, a serious extracranial injury was defined as any extracranial injury visible on a radiological examination performed in the ED.

The CCHR and NOC were applied to the subset of the cohort where they were applicable according to their original criteria, while the NEXUS II, NICE, and SNC were applied to the entire cohort. To enable a thorough analysis of all guidelines, inclusion and exclusion criteria for CCHR and NOC were modified. The requirement for amnesia, loss of consciousness, and disorientation to be eligible for guideline use was removed. Exclusion criteria indicating an increased risk for ICI (e.g., altered level of consciousness in NOC or anticoagulant treatment in CCHR) were instead viewed as the guideline recommending CT scanning, as was done by Smits et al. (52). These adaptations were called adapted Canadian CT Head Rule and adapted New Orleans Criteria. Theoretically, these adaptions should result in increased sensitivity and reduced specificity compared to the originals.

The recommendations regarding retrospective research by Vassar et al. were followed to ensure the highest possible study quality. They were presented as a list of common mistakes with recommended amendments:

1. Failure to create well-defined, clearly articulated research questions
2. Failure to consider sampling issues a priori
3. Failure to adequately operationalize variables in the study
4. Failure to train and monitor data abstractors
5. Failure to use standardized abstraction forms
6. Failure to create an adequate procedural manual for data abstraction
7. Failure to explicitly develop inclusion and exclusion criteria
8. Failure to address interrater or intrarater reliability

An inter-rater agreement was calculated based on Cohen’s kappa and percentage agreement through a second interpretation of the medical records of 100 randomly chosen patients in the cohort(101,102).

Statistics

All statistical analyses were performed using IBM SPSS® 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Dichotomous variables regarding the need for CT were constructed for each guideline. Theoretical CT rate, sensitivity, specificity, negative predictive value, positive predictive value, and difference in CT rate when compared with the actual CT rate in the cohort was calculated. The outcomes of each guideline were treated as categorical variables and analyzed with Pearson's χ^2 test. The 95% confidence interval around the estimated CT rate for each guideline was calculated using an online calculator(103,104).

Paper III

The study was performed as a retrospective review of medical records from patients initially seeking care at Helsingborg hospital after sustaining a CT verified ICI with an initial GCS-score of 14-15 between the 1st of January 2014 and the 31st of December 2019. Eligible patients were identified through ICD-10 codes consistent with ICI registered at any point during the current admission. Inclusion and exclusion criteria can be seen in figure 3.

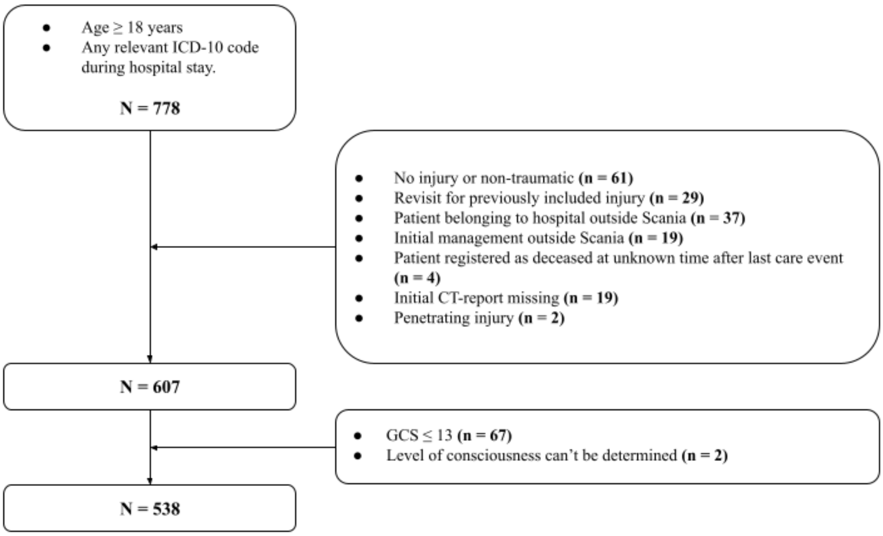

Figure 3:
Inclusion and Exclusion criteria for paper III

The first exclusion step was to ensure a correctly sampled cohort with minimal risk of missing information about either initial presentation or potential adverse outcomes within 30 days. The second exclusion was performed to ensure that only patients with mTBI were included.

A detailed list of which parameters to extract was compiled before the start, and a single data collector did the review. The document was continuously reviewed and updated as data collection proceeded to ensure a consistent interpretation. The following parameters were extracted along with epidemiological data.

1. The number of days admitted to hospital.
2. Rockwood Clinical Frailty Scale Score.
3. Initial loss of consciousness.
4. Seizure, prehospital, or in ED.
5. Vomiting, prehospital, or in ED.
6. Mechanism of injury.
7. Initial RLS-85 level.
8. Blood pressure upon presentation.
9. Oxygen saturation upon presentation.
10. Respiratory rate upon presentation.
11. Hemoglobin upon presentation.
12. Platelet count upon presentation.
13. Result of initial neurological examination.
14. Presence of intoxication.
15. Treatment with anticoagulants or platelet inhibitors.
16. Type of ICI.
17. Number of ICI.

18. Comment on the presence of midline shift.
19. Comment regarding the size of the largest hemorrhage.
20. Concomitant injuries.
21. Other radiological examinations that were performed in the ED.
22. Outcome within 30 days of initial presentation.

The following assumptions and adjustments were made to enable analysis.

- Not mentioning a particular parameter was interpreted as negative. Ambiguous parameters were interpreted as positive (e.g., "possibly unconscious" = Unconscious).
- The GCS score was interpreted from RLS-85 in the same manner and for the same reasons as in paper II.
- If the size of the largest hemorrhage was not mentioned, the data collector read the radiology report and identified hemorrhages that were very likely less than 5 mm based on how the hemorrhage was described (e.g., "minimal subarachnoid hemorrhage" or "punctate parenchymal hemorrhage."

The outcome was defined as death, in-hospital intervention (craniotomy, burr hole, placement of an intracranial pressure monitor), admission to ICU due to ICI, need of emergency intubation due to ICI, decreased consciousness, seizure within 30 days of initial presentation, administration of hypertonic saline/mannitol or administration of intravenous antibiotics for basal skull fracture.

Statistics

All statistical analyses were performed using IBM SPSS ® 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp) for Windows. New variables were constructed based on the extracted parameters to determine which patients would be eligible for discharge based on either the BIG or the mTBI-RS. If a patient was deemed eligible for discharge according to any of the guidelines, an additional review of the radiology report was done to ensure no cerebellar or intraventricular hemorrhages were missed and verify the measurement of the largest hemorrhage. After this double-check, sensitivity and specificity for both guidelines were calculated. The two proportions theoretically eligible for discharge were compared using a Chi-squared test. A second analysis including patients with RLS-85 3 (GCS 9-13) to evaluate the impact of excluding them in the original analysis. A P-value of less than 0.05 was considered significant, and a 95%-confidence interval was used.

Paper IV

The goal with paper IV was to explore which factors that ED physicians believe can affect guideline adherence and how this can be improved. The local TBI guideline was used as an example and can be seen in figure 4. Along with the document in figure 4, the flowchart in figure 1 is also attached when accessed at the hospital.

Helsingborgs lasarett En del av Region Skåne	Medical Guideline	
Specialty: Surgery / Emergency Medicine	Written by: Tomas Vedin / Marcus Edelhamre Responsible for facts: Tomas Vedin / Marcus Edelhamre Approved by: Jörgen Wenner / Fredrik Jonsson / Poul Kongstad	
Created: 2014-01-27	Revised:	Best before: 2015-12- 31
Keyword: head injury, commotio cerebri, traumatic hemorrhage, concussion, head trauma, contusio cerebri, contusion, adult		PM No:

Management of head-injured patients in the emergency department

Per the Scandinavian guidelines, S-S100B is incorporated in assessing patients who have had a head injury. This guideline only covers adult patients (18 years or older).
The algorithm on page 2 applies to ALL adult patients with isolated head trauma, regardless of amnesia, loss of consciousness, vomiting, etc., who are NOT unconscious when entering the emergency room. For treatment of an unconscious patient, see below.

Multi trauma patients should NOT be included in this algorithm. These patients should be managed according to ATLS ™.

Routines for hospitalization of a head-injured, conscious patient

When hospitalized with a possible (s100B> 0.1ug / l) or CT-verified bleeding, the patient should primarily be cared for at KAVA, secondarily at AVA-H. The admitting physician must prescribe the frequency of checks (wakefulness, pupil reaction, pulse, and blood pressure) at admission. If there is a high suspicion of bleeding, assessments are conducted every 15 minutes until a diagnosis has been made. After that, the controls can usually be sparsed out depending on the extent of the damage. If the suspicion of bleeding is lower (for example, hospitalization instead of CT) or if the bleeding is so minor that the patient's consciousness is unaffected, checks every two to two hours are often sufficient, which can eventually be reduced to every four hours. Paracetamol IV is mainly used as pain relief. (1gx4) because NSAIDs increase the tendency to bleed, and opiates affect consciousness. These patients should fast during the observation period and may, in the meantime, be supplied with a slow infusion of Ringer's acetate IV.

Management of unconscious patients

The basic rule is that unconscious patients (RLS 4-8) should be intubated and monitored at the ICU or in the emergency department until they can be transported to the neurosurgical unit in Lund for intracranial pressure monitoring or surgery. The patients who are not relevant for neurosurgical care are cared for in Helsingborg. Still, a liberal attitude to a new contact in the event of deterioration must be considered.

Burr hole craniotomy can be performed in Helsingborg in selected, very acute cases, but this should only be carried out on direct vital indication and preferably after contact with neurosurgical expertise or trauma care in Helsingborg.

Transfer of a head-injured patient to the neurosurgeon in Lund

For general information on secondary ambulance transport, see Directive 44 from RSPE. Transportation must be by emergency (<15min, for patients who can not be stabilized in Helsingborg, see information sheet 16 from RSPE) or semi-emergency ambulance (15-45 min, patients who can be stabilized in Helsingborg, see information sheet 17 from RSPE) Anesthesia staff and should accompany in the ambulance. If there is time, you can choose an ICU ambulance instead as anesthesia staff accompanies and saves this resource in Helsingborg, see information sheet 84 from RSPE. It usually arrives at Helsingborg in 40 minutes. The patient must be accepted by the neurosurgeon on call.

The transferring doctor in Helsingborg must also contact the surgeon's emergency room in Lund and the trauma nurse at the emergency room in Lund to announce that a head-injured patient is being transferred so that the patient can be examined secondarily in the trauma room at the emergency room in Lund. The ambulance staff must alert SUS / Lund 15 minutes before arrival for the trauma team with the neurosurgeon to show up, see directive 87 from RSPE.

If there is a high risk of squeezing, you can gain time during the ambulance transport by giving Mannitol® (150 mg/ml). After contact with the neurosurgeon on call, this is administered at a dose of 1.5-2 grams/kg body weight (10 to 13 ml/kg body weight) infused over 30 to 60 minutes.

Figure 4:
Local TBI guideline at Helsingborg hospital, except for the flowchart in figure 1. Presented here in English, original in Swedish.

Semi-structured interviews were conducted with physicians of varying levels of experience who had worked for at least four weeks in the ED during 2017. The interview questions were centered around general thoughts about the use of guidelines, thoughts about the local TBI guidelines, the perceived effect on guideline adherence from external factors, and reflections regarding barriers and facilitators of guideline adherence. Questions about each topic were written beforehand through a review of relevant research and discussion amongst the authors. In order to explore subjects further, branching questions were asked when appropriate. Before starting the inclusion, a pilot interview was conducted(105).

A predefined number of 30 interviews was chosen before the start because it was deemed likely to reach thematic saturation, based on a study by Guest et al. (2006). Thirty interviews were performed, and 28 were included in the final analysis. Saturation regarding emerging themes and provided answers was reached gradually and reached a critical point at around 20 interviews. Further interviews did not deepen our understanding of the topic at hand, and answers started to become redundant. This was, however, not apparent until the analysis of all 30 interviews was performed. The remaining interviews were still performed due sample size being agreed upon before the start of the study (106,107).

The interviews were conducted by a single interviewer over three months and were recorded and transcribed ad verbatim by external consults. Before coding, six categories were created a priori to create a framework for organizing the codes. These were:

- Internal factors that increase guideline use,
- Internal factors that decrease guideline use,
- External factors that increase guideline use,
- External factors that decrease guideline use,
- Positive aspects of the local TBI guideline and
- Negative aspects of the local TBI guideline.

The analysis of the transcribed interview was done within the framework of thematic analysis. It was chosen since it does not require a deep knowledge of different qualitative, analytical methods and offers a more accessible form of analysis for those not previously experienced in qualitative research(108).

The analytical process consists of thorough familiarisation with the data (transcribed interviews) and initial codes. A code is a “word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data” (Saldana, 2013 p. 3). It is the essential element of the raw data that can be assessed in a meaningful way regarding the phenomenon at hand. The codes are later organized into themes and subthemes. A theme is some level of patterned response or meaning within the dataset and captures essential information regarding the research question. The themes are repeatedly reviewed and refined to ensure a satisfactory thematic map of the data and, when appropriate, organized into sub-themes. A sub-theme is a theme-within-a-theme that can structure large themes and demonstrate a hierarchy of meaning(108,109).

The interviews were coded by a single coder, adding codes as they emerged. An interrater percentage agreement was calculated by having two additional authors review the codes and determine if they agreed. A percentage agreement of 93.2% and 97.4% were received, respectively. After all the interviews had been coded, thematization was conducted by three of the authors on three separate occasions.

Ethics

The ethical review board in Lund approved papers I-II, and the Swedish ethical review authority approved paper III before start. The need for informed consent was deemed not necessary by the ethical review board

An ethical application was submitted for the study that led to paper IV. However, since the study did not collect any sensitive information, the need for ethical approval was waived as per the Swedish ethical review Act by the Swedish ethical review authority.

Paper I-III consist of retrospective reviews of medical records, sometimes conducted years after the head injury. The reviews are limited in their extent, aiming only to view and collect data relevant to the research questions at hand. However, due to the electronic health record structure, other potentially sensitive data regarding the patients' health status can be seen by accident. This risk was minimized by having only a single person performing the data collection, except for the records viewed for calculating inter-rater agreement (paper II) and double-checking measurements of intracranial hemorrhages (paper III). The data were pseudonymized immediately using a code key and only analyzed and presented on a group level. Taking all these factors into consideration, the overall integrity breach associated with these studies was deemed low by all participants in the research group

The fact remains, however, that no informed consent was retrieved before the start. The general rule for research is that it must be voluntary and that the patients' medical records are for their and their health care personnel’s eyes only. Even though the ethical review was conducted and ethical approval was granted, these principles were infringed on. It can be argued that attempting to acquire informed consent from patients regarding an injury that occurred several years ago would at best provide a minimal, highly selected subset of patients, rendering it practically impossible to conduct this type of research with good quality. The retrospective chart review is a cornerstone in medical research as both a means to test findings from previous studies and generate hypotheses for future prospective studies. Inhibiting this type of research risks having downstream effects, with fewer possibilities to verify previous studies or design new ones that could lead to less-than-optimal care for future patients.

Another dilemma associated with retrospective chart reviews is that patterns not apparent to the physicians in the ED can be identified when viewed in a larger context. A theoretical example would be that if it became evident that a physician practicing in the ED has consistently bad outcomes. Reporting this pattern to one of the physician’s superiors could potentially prevent further patients from getting a supposedly sub-par treatment, but at the same time risk bringing false accusations towards a colleague if the bad outcomes are attributed to other causes. Another theoretical example would be if a patient sought care repeatedly for head injuries with apparent signs of domestic abuse. This would not necessarily have been obvious to individuals in a busy ED that do not have time to review the chart in detail.

A solution in these cases could be a group discussion with senior physicians and researchers to determine the most appropriate course of action in each case.

The ethical questions regarding paper IV are much less pronounced since it only involved consensual participants and did not touch on any information that can be classified as sensitive, but some issues still came forward. Through the interviews performed, the interviewer received a rather deep insight into the everyday practice of the interviewed physicians. An ethical dilemma would be if a potentially harmful practice of the interviewed physician came up during the interviews. The interviewees were, in many cases, colleagues with the interviewer, expecting confidentiality regarding what was said during the interview. The information acquired could be passed on to the interviewee’s superior to protect future patients, but this would violate the agreement upon which these interviews were conducted in the first place. This would also potentially erode the trust in the research process, making it harder to recruit participants in future studies and thus potentially lead to lower quality evidence. Had this occurred, a discussion with the interviewee would have been performed to deepen the understanding of the situation. If the practice was obviously, seriously harmful and the interviewee maintained their standpoint regarding continuing it, a possible solution would be to contact the superiors in the department for further discussion.

Results

Paper I

The aim was to evaluate characteristics of adults seeking medical care after a head injury to identify features of intracranial hemorrhage. One-thousand six-hundred thirty-eight patients met our inclusion criteria. A majority of the cohort was male (54.5%), and the median age was 58 years (Q_1=35, Q_3=77, IQR 42), with a peak at 24 years of age. Figure 5 shows the age distribution of the cohort.

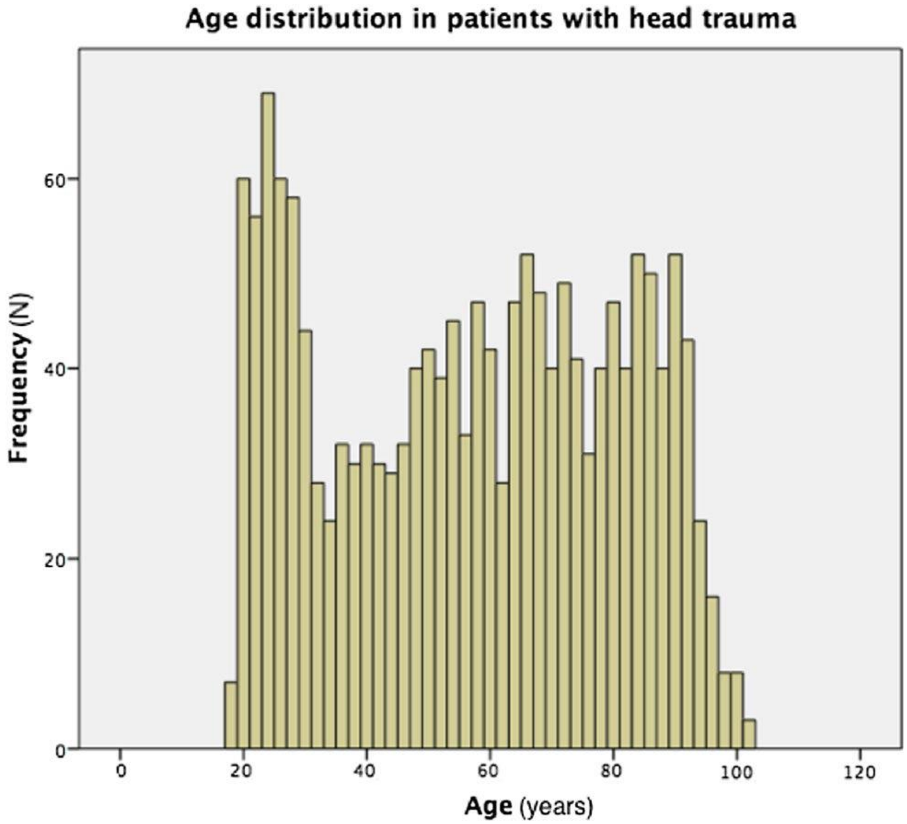

Figure 5:
Age distribution of cohort in paper I

One thousand three hundred seventy-eight patients (84.1%) had either minimal (456/1638, 27.8%) or mild (922/1638, 56.3%) TBI. A total of 842 CTs were performed, corresponding to 51.4% of the cohort. Intracranial hemorrhage was found in 70 (4.3%) patients, seven (0.4%) were cared for in the ICU, and 5 (0.3%) required neurosurgical intervention. Most patients where trauma energy level could be determined suffered low-energy trauma (1251/1360, 92%). Low-energy trauma was defined as either ground-level falls or lesser traumas to the head from external objects. The population at risk for TBI in the Helsingborg hospitals' catchment area in 2014 was estimated to be 278,367 people through changes in the population between 2020 and 2021. These numbers gave a total incidence of 554.6/100,000 and 114/100,000 for TBI being admitted(110,111).

The incidence of intracranial hemorrhage in patients under treatment with anticoagulants or platelet inhibitors was 2 and 2.74 times that of the entire cohort, respectively.

Four parameters significantly associated with intracranial hemorrhage in this cohort were identified through multiple logistic regression: increasing age, mTBI as the degree of head injury, new neurological deficit, and low-energy trauma mechanism.

A subgroup analysis performed in patients under the age of 59 who did not take platelet inhibitors nor anticoagulants and was subjected to a low-energy trauma showed no intracranial hemorrhages. This group constituted 50.4% (826/1638) of the cohort.

Paper II

This paper sought to compare the performance of five international guidelines for managing patients with TBIs and determine how a theoretical application of each guideline would affect the CT rate. One-thousand six-hundred seventy-one patients were demographically analyzed. The median age was 64 years (Q_1=39, Q_3=80, IQR 41), 53.1% were male, and the most common mechanisms of injury were falls from below 1 meter (1033/1672, 61.7%) followed by assaults (118/1672, 7.1%). Between the ages of 18-29, 35.6% had fallen from any height as the stated mechanism of injury. The corresponding number for patients aged 70-89 was 95.4%. Road traffic accidents constituted 108/1672 (6.5%) of the cases. 1649/1672 (98.7%9) had mTBI, 12/1672 (0.7%) hade moderate TBI and 10/1672 (0.6%) had severe TBI. The age distribution of the cohort can be seen in figure 6.

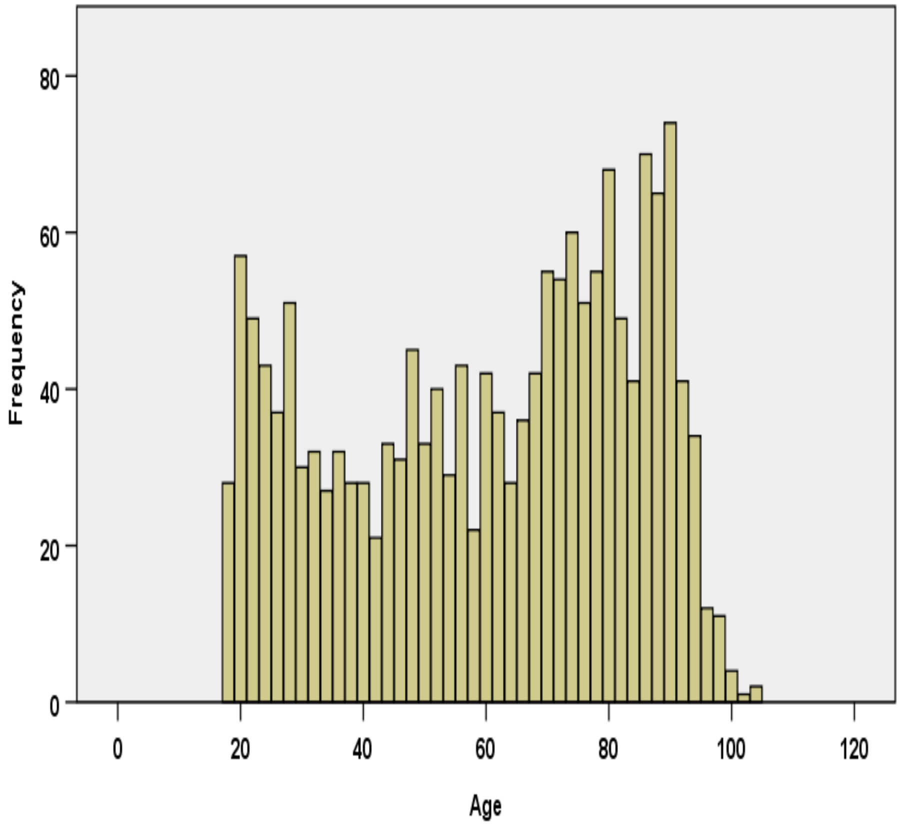

Figure 6
Age distribution of the cohort in paper II

Similarly, as in paper I, the population at risk for TBI was estimated post hoc through changes in the size of the population between 2020 and 2021, to 285,999 people(110,111). A total incidence for TBI of 584/100,000, 136/100,000 for TBI requiring admission, and 2.92/100,000 for dying due to TBI was calculated.

The last step of the exclusion process portrayed in figure 2 (p. 34) was performed to enable comparison between the five guidelines, yielding 1353 eligible patients. Head CT was performed in 825 (61%) cases, and 70 (5.2%) showed at least one type of intracranial hemorrhage. Three (0.2%) patients required neurosurgical intervention, and four (0.3%) patients died from head injuries. Each patient that died or required intervention was identified by all of the guidelines when applicable. Patient characteristics and risk factors for intracranial hemorrhage can be seen in table 1.

Table 1.
Description and presence of risk factors for intracranial hemorrhage in patients eligible for guideline comparison

Parameter	Category	N (%)	Missing (%)
Age		65 (40-81) [a]	0 (0.0)
Male		747 (53.8)	0 (0.0)
Coagulopathy		9 (0.6)	51 (3.7)
Anticoagulation		186 (13.4)	47 (3.4)
Platelet inhibitors		173 (12.5)	45 (3.2)
RLS-85	1	1333 (96.0)	0 (0.0)
	2	49 (3.5)	0 (0.0)
	3	6 (0.4)	0 (0.0)
GCS	15	1331 (95.9)	0 (0.0)
	14	50 (3.6)	0 (0.0)
	9-13	7 (0.5)	0 (0.0)
Loss of consciousness	Certain	272 (19.6)	277 (20.0)
	Suspected	104 (7.5)	n/a
Amnesia		301 (21.7)	672 (48.4)
Amnesia >30 min		12 (0.9)	86 (6.2)
Headache		261 (18.8)	811 (58.4)
>2 vomits		30 (2.2)	692 (49.9)
Dangerous Mechanism		57 (4.1)	35 (2.5)
Post-traumatic seizure	Certain	10 (0.7)	0 (0.0)
	Suspected	4 0.3)	n/a
Intoxication		324 (23.3)	758 (54.6)
Abnormal behavior in ED		66 (4.8)	0 (0.0)
Abnormal alertness in ED		99 (7.1)	0 (0.0)
Signs of depressed skull fracture		111 (8.0)	1115 (80.3)
Signs of basilar skull fracture		18 (1.3)	1225 (88.3)
Scalp hematoma		66 (4.8)	1192 (85.9)
Visible injury above clavicles		1044 (75.2)	188 (13.5)
Neurological deficit		60 (4.3)	919 (66.2)
S-S100B > 0.10 µg/L[a]		240 (59.1)	n/a
CT Head performed		845 (60.9)	n/a
Intracranial hemorrhage[c]	Total	70 (5.1)	n/a
	Subdural	29 (41.4)	n/a
	Subarachnoidal	29 (41.4)	n/a
	Epidural	4 (5.7)	n/a
	Other	30 (42.9)	n/a
Skull fracture	Total	18 (1.3)	1(0.1)
	Basilar	11 (61.1)	n/a
	Linear, no depression	5 (27.8)	n/a
	Linear, depression	1 (5.6)	n/a
	Comminute, no depression	1 (5.6)	n/a
	Comminute, depression	0 (0.0)	n/a
Neurosurgery		3 (0.2)	n/a
Death due to ICI		4 (0.3)	n/a

a) Median (Q_1-Q_3), b) Not all patients were sampled, c) Some patients had multiple hemorrhages.

The NOC could be applied to 256 (18.9%) patients, suggesting CT in 249 (97.2%). This subgroup included 29 (41.4%) intracranial hemorrhages and no deaths due to TBI or the need for neurosurgical intervention. The CCHR could be applied to 394 (29.1%) patients, suggesting CT in 251 (63.7%) cases. This subgroup included 36 (51.4%) intracranial hemorrhages and no deaths due to TBI or the need for neurosurgical intervention. The primary outcome (detection of intracranial injuries requiring neurosurgical intervention or resulting in death) could not be assessed for either NOC or CCHR in their original form.

The NICE, the SNC, and the NEXUS II guidelines could be applied to the entire cohort, suggesting CT in 595 (44%), 703 (52%), and 891 (65.9%) cases, respectively. All guidelines identified the three patients who needed neurosurgical intervention and the four patients who died due to their ICI, but each guideline failed to identify all patients with ICI.

The theoretical CT-rate, sensitivity, specificity, negative predictive value, positive predictive value, and theoretical difference in CT-rate in the current cohort for each guideline is presented in table 2.

Table 2:
Theoretical performance of evaluated guidelines and their theoretical effect on CT-rate. Presented with a 95% confidence interval.

Guideline	CT-rate	Sensitivity	Specificity	∆ CT-rate
a-NOC	96.7% (95.6-97.6%)	97.1% (90.1-99.7%)	3.3% (2.4-4.5%)	+ 35.8% (P = <0.0001)
a-CCHR	65% (62.4-67.5%)	87.1% (77-94%)	36.2% (33.6-38.9%)	+ 4.1% (P = 0.025)
NEXUS	65.7% (63.1-68.2%)	85.7% (75.3-92.3%)	35.4% (32.8-38%)	+ 4.8% (P = 0.0089)
NICE	43.7% (41.1-46.4%)	75.7% (63.1-83.5%)	58% (55.4-60.7%)	- 17.2% (P = <0.0001)
SNC	52% (49.4-54.7%	88.6% (78.7-94.9%)	49.9% (47.2-52.7%)	- 8.9% (P = <0.0001)

Abbreviations: CT = Computerized Tomography, a-NOC = Adapted New Orleans Criteria, a-CCHR = Adapted Canadian CT Head Rule, NEXUS = National Emergency X-Radiography Utilization Study II, NICE = National Institute for Health and Care Excellence guideline, SNC = Scandinavian Neurotrauma Committee guideline.

According to Cohen's kappa, most parameters had a good or very good interrater agreement, and the calculated percentage agreement was over 90% in all but one parameter.

Paper III

This paper aimed to evaluate the performance of mTBI-RS and BIG in patients with ICIs and to determine how many patients that potentially could have been discharged home directly from the ED. Five hundred thirty-eight patients were included. Patient characteristics can be seen in table 3. Ten (1.9%) were eligible for discharge according to mTBI-RS, and eight (1.5%) were eligible for discharge according to BIG (P=0.63).

Table 3:
Patient characteristics

Parameter	Category	N (%)[a]	Missing (%)
Age	Median (Q_1-Q_3)	76 (63–85)	n/a
Sex			n/a
	Female (%)	216 (40.1)	
	Male (%)	322 (59.9)	
Days admitted	Median (Q_1-Q_3)	4 (2-9)	n/a
RCFS			5 (0.9)
	Under 50 (%)	58 (10.9)	
	1–3 (%)	267 (50.1)	
	4–6 (%)	183 (34.3)	
	7–9 (%)	25 (4.7)	
Loss of consciousness			188 (34.9)
	Yes (%)	134 (38.3)	
	Unsure (%)	111 (31.7)	
	No (%)	105 (30)	
Seizure, prehospital or ED	Yes (%)	11 (2)	520 (96.7)
Vomiting, prehospital or ED	Yes (%)	78 (14.5)	432 (80.3)
Mechanism of injury			14 (2.6)
	Ground-level fall (%)	370 (68.8)	
	Elevated fall (%)	67 (12.5)	
	Traffic accident (%)	54 (10)	
	Assault (%)	20 (3.7)	
	Other (%)	10 (1.9)	
Documented RLS level	Yes (%)	321 (59.7)	n/a
GCS (Converted from RLS-85)			n/a
	15 (%)	435 (80.9)	
	14 (%)	103 (19.1)	
Blood pressure	Mean MAP mm Hg (SD), Min-Max	107.3 (18.3), 37–175	8 (1.5)
Oxygen saturation	Mean % (SD), Min-Max	96.5 (2.8), 75–100	2 (0.4)
Respiratory rate	Mean Breaths/min (SD), Min-Max	19.1 (4.2), 10–42	8 (1.5)
Haemoglobin	Mean g/L (SD), Min-Max	134.9 (18.8), 69–191	32 (5.9)
Platelet value	Mean 10^9/L (SD), Min-Max	236.3 (85.6), 5–852	98 (18.2)

Intracranial injury[b]		n/a
aSDH (%)	281 (52.2)	
SAH (%)	234 (43.5)	
IPH (%)	138 (25.7)	
naSDH (%)	79 (14.7)	
EDH (%)	23 (4.3)	
Location not specified (%)	38 (7.1)	
Other, DAI & Edema (%)	17 (3.2)	
Linear skull facture (%)	59 (11.0)	
Comminute skull fracture (%)	7 (1.3)	
Basilar skull fracture (%)	76 (14.1)	
Adverse events in 30 days		n/a
Death (%)	37 (6.9)	
In hospital intervention (%)	114 (21.2)	
ICU admittance (%)	82 (15.2)	
Intubation (%)	22 (4.1)	
Decreased consciousness (%)	94 (17.5)	
Seizure (%)	34 (6.3)	

a) Except for “Age” and “Days admitted”, which are presented as median (Q_1-Q_3), b) Some patients had more than one injury.

ED = Emergency Department, RLS-85 = Reaction Level Scale 85, GCS = Glasgow Coma Scale, MAP = Mean Arterial Pressure, aSDH = Acute subdural hematoma, SAH = Sub-arachnoid hemorrhage, IPH = Intra parenchymal hematoma, naSDH = Non-acute subdural hematoma, EDH = Epidural hematoma, DAI = Diffuse axonal injury, ICU = Intensive care unit., RCFS = Rockwood Clinical Frailty Scale

Parameters used to determine if a patient was eligible for discharge according to either guideline can be seen in table 4.

Table 4:
Parameters involved in guideline comparison

Parameter	Category	N (%)	Missing (%)
GCS (Converted from RLS-85)			n/a
	15 (%)	435/538 (80.9)	
	14 (%)	103/538 (19.1)	
Normal first neuro exam	Yes (%)	378/487 (77.6)	51 (9.5)
Intoxicated	Yes (%)	100/538 (18.6)	0 (0)
Oral blood thinner			0 (0)
	Anticoagulation (%)	110/538 (20.4)	
	Platelet inhibitors (%)	148/538 (27.5)	
	Any (%)	252/538 (46.8)	
Number of injuries on CT			n/a
	1 (%)	263/538 (48.9)	
	2 (%)	171/538 (31.8)	
	3 (%)	69/538 (12.8)	
	4 (%)	27/538 (5.0)	
	≥5 (%)	8/538 (1.5)	
Comment on midline shift[a]	Yes (%)	196/514 (38.1)	n/a
Midline shift on initial CT[a]	Yes (%)	95/514 (18.5)	n/a
Comment on hemorrhage size[a]	Yes (%)	352/514 (68.5)	n/a
Hemorrhage under 5 mm[a, b]	Yes (%)	82/514 (16)	n/a
Any skull fracture	Yes (%)	119/538 (22.1)	n/a
ISS ≥3 (excluding head)	Yes (%)	112/536 (20.9)	2 (0.4)

a) Patients with isolated fractures were not included in these parameters, b) Written in or interpreted from radiology report.

GCS = Glasgow Coma Scale, RLS-85 = Reaction Level Scale 85, CT = Computerized Tomography, ISS = Injury Severity Score.

The mTBI-RS had a sensitivity of 100% (CI 98.1–100%) and a specificity of 2.9% (CI 1.4–5.2%). The BIG had a sensitivity of 100% (CI 98.1–100%) and a specificity of 2.3% (CI 1–4.5%) for any outcome within 30 days of initial presentation, which can be seen in table 5

Table 5:
Sensitivity and specificity for BIG and mTBI-RS

Guideline	Sensitivity (95% CI)	Specificity (95% CI)
BIG	100% (98.1–100%)	2.3% (1.0-4.5%)
mTBI-RS	100% (98.1–100%)	2.9% (1.4-5.2%)

BIG = Brain Injury Guidelines, mTBI-RS = Mild Traumatic Brain Injury Risk Score, CI = Confidence Interval

Paper IV

This paper sought to evaluate barriers and facilitators to guidelines adherence in the ED and ways to improve the local TBI guideline. Eight main themes and 19 sub-themes were identified. Themes, sub-themes, and representative quotes can be seen in table 6.

Twenty-six participants (92.8%) had a positive attitude toward guidelines in general and stated that they were especially useful for inexperienced physicians. The remaining two were neutral, stating the risk that guidelines may impair individual tailoring of treatment. Twenty-one participants (75%) had either knowledge about or had used the local guideline for TBI.

Themes regarding guideline use

Theme 1: Content and Presentation

According to the interviewees, a guideline should be concise without too much non-essential information. A minority of the interviewees believed disease-specific background information to be positive. The guideline should be written logically, easy to understand at a glance, and, when appropriate, use well-designed visual aids (such as flowcharts). The recommendations should be clearly stated to avoid misinterpretation, and there should not be any doubt when a guideline can be used.

Theme 2: Effects on care and caregivers

This theme contained three sub-themes: “Guidelines’ effect on patient care”, “Guideline usage and doctors’ emotions” and “Equality of care and resource utilization”.

It was important for a guideline to provide clinical guidance or hints in their management in the first sub-theme. According to some, instructions regarding subsequent care, follow-up, or reminders for investigation of often co-existing conditions were also important.

In the second sub-theme, most interviewees stated that they felt safer in their decision-making when they could lean on a guideline. Guidelines could also lead to more efficient care with less decision fatigue. However, guidelines could lead to premature diagnostic closure or overly rigid management, leading to less individualized care.

In the third sub-theme, the interviewees thought that guidelines led to more equal and standardized care. Some believed that strict guideline adherence could decrease resource utilization, but almost as many believed that strict guideline adherence would lead to increased resource use.

Theme 3: Availability

This theme consists of four sub-themes – “Technical conditions”, “Access time”, “Knowledge about guidelines and where to find them” and “Finding the right one among many”.

The first sub-theme brought forward various technical aspects that affected guideline adherence. All interviewees viewed technical issues as a barrier, especially having guidelines that are hard to find on the local intranet. The retrieval process was difficult and inconvenient according to a non-negligible minority, and only a few found no difficulties finding the guidelines. The fact that guidelines are located in different places on the intranet was also an obstacle, along with the need for personal sign-in, long loading times, old/corrupted documents, and frequent intranet redesigns.

The second sub-theme, access time, brought forward the belief that physical guideline documents available on site could increase use. An improved search function on the intranet and a direct link on the desktop could also increase use.

Sub-theme four emphasizes the importance of knowing that a guideline exists and where to find them to use them.

Sub-theme five was centered around the fact that guideline adherence was perceived as difficult by having too many different guidelines and having non-medical guidelines mixed in with them on the intranet.

Theme 4: Trust in the guidelines

Two subthemes, “Collective perception” and “Scientific evidence” were distinguished. “Collective perception” touches on the importance of a guideline being developed by people with the right competence and through a rigorous process to have trust in the guideline. Some view guidelines that are national or publicly available as more reliable because of the increased public scrutiny. “Scientific evidence” is about the belief that if a guideline is to be trusted, it should be based on valid, recently conducted studies and that physicians had lower trust in the guideline if it is not.

Theme 5: Workload

This theme is further divided into three sub-themes – “Subjective stress”, “Work environment” and “Amount of time at disposal”. As previously described, being stressed could negatively affect guideline adherence, especially when combined with a cumbersome retrieval process. On the contrary, guideline adherence could increase when stressed because it can make it easier to sort the thoughts and avoid missing vital steps.

High levels of in-hospital bed occupancy and a high number of patients waiting in line at the ED can sometimes lead to decreased levels of guideline adherence when following a guideline would lead to additional procedures, tests, or admissions that were deemed unnecessary. The recommendation of admitting patients with anticoagulant treatment and a normal CT after TBI was often mentioned as a specific example of when a guideline was not adhered to. Shortage of nursing staff could also lead to lower guideline adherence. A lack of time at one's disposal was also often mentioned as a reason for not following a guideline in having too many things to do at any given time and thus not taking the time to look for, read and apply local guidelines.

Theme 6: Culture

This theme was subdivided into “Attitudes among staff” and “leadership”. Using a guideline when working in the ED was considered the norm according to a majority of interviewees. They had either witnessed a peer use a particular guideline or been instructed to do so themselves. Involving nurses in guideline development and keeping them updated on eventual changes could lead to higher levels of adherence since they are involved in several steps of the management. When present, peer pressure from other professions in the ED could lead to lower guideline adherence, especially when adhering to a guideline would cause them more work or keep the patient in the ED for longer.

Instructions from senior colleagues and management can affect guideline adherence, and several interviewees believed that encouragement from superiors to use a specific guideline would increase use. Guideline adherence can also decrease when non-adherence to a specific guideline is instructed by a superior.

Theme 7: Patient-related factors

The sub-theme “Incompatibility between patient and guidelines” states that if a patient were deemed not to benefit from following a particular guideline, some of the interviewees would stray from using it. Examples of this could be patients whose disease severity was either under or overstated by the specific guideline or if a patient had too many co-morbidities to be eligible for treatment.

Complex cases might lend themselves to be less applicable for adhering to a specific guideline. It might be hard to determine which guideline to use, or the patient might present with multiple conditions whose treatments, at least partly, contradict each other.

Theme 8: Doctor-related factors

It was believed that individual doctor competence could affect guideline adherence. If a doctor perceived oneself as less competent in a specific area, the doctor might be more inclined to use a guideline. A belief that using guidelines was an excellent way to stay updated about current management recommendations was also presumed to lead to higher levels of guideline adherence.

More experienced doctors were believed to better tailor treatments to individual patients than a guideline would. They tended not to use guidelines as much as less experienced doctors.

Guideline adherence could also be affected by fear of being viewed as bothersome, to cover ones’ back in case of an adverse event, or including additional tests when another similar test was already to be performed. For example, including a CT-scan of the head automatically when a CT-scan of the cervical spine is performed.

Table 6:
Themes, subthemes and one or more representative quote from each subtheme.

Main Themes & Subthemes	n/total
Content and presentation	**28/28**
”There are guidelines that leave some room for interpretation with regards to clinical evaluation of a patient, and it can be hard for a novice doctor that hasn’t seen many such patients to separate pathology from normal. So, the younger…or more novice, a doctor is, the more information a guideline should contain and the more experienced you are, the simpler and easier the guideline.” #16 - Specialist in Emergency Medicine.	
“It is pretty good with flowcharts where you can see that “Yes, okay, if it gets to this I will go to this box, and if it gets to that, I will go to that box.” I think that is pretty easy to understand.” #5 - Resident in Emergency Medicine.	

”That there are clear rules regarding on whom the guideline is applicable and that it is easy to follow, that there are no uncertainties within the guideline.”
13 - Resident in Emergency Medicine.

Effect on care and caregivers	**28/28**
Guidelines’ effect on patient care	**18/28**

“Then I think it should say a little about how to proceed and investigate. What is especially important in the history and not important in the history? Which laboratory tests should you order? Then I think it should say how to interpret different findings and how to proceed with processing, how to, for example, admit the patient or discharge with a certain medicine and at what dosages […] I have more than once come across colleagues who have only assessed the head injury and not the cervical spine.”
20 - Resident in General Surgery.

Guideline usage and doctor emotions	**28/28**

"What you have heard from older colleagues is that it makes you stupid, that you stop thinking a little […] You just do as the guideline says and sometimes you have to think outside the box. I can agree with that, but at the same time, you develop guidelines to reduce healthcare injuries. I often think that you miss things or that you make mistakes.”
4 - Resident in Emergency Medicine.

“… Otherwise, I only think it is an advantage for the patients because it is faster, the doctor knows what to do, it is like no decision fatigue, you know exactly how to proceed, you know how to manage the patient. So, in that sense, I think it is only beneficial."
18 - Intern.

Equality of care and resource utilization	**18/28**

“Because then you know that all patients are treated in the same way. So, it is a sign… relatively safe, compared to when people read different books and act accordingly. Then everyone gets a different kind of care."
26 - Intern.

“So, you may get a gut feeling or that you have met so many patients, and the patient you have in front of you may not fit in the guideline. But still, according to the guideline, you have to do… So maybe you do order a lot of unnecessary tests or examinations that you think is a little unnecessary.”
28 - Resident in Emergency Medicine.

Availability	**28/28**
Technical conditions	**28/28**

"So, I think the intranet is the worst in the world. It's so… yes, but it's such a shame. There are a lot of clicks and then you often end up wrong."
10 - Intern.

"I think it would have taken a collective approach for them to be accessed easily on the intranet in some way, that they are not divided into different departments."
24 - Resident in General Surgery.

Access time	**24/28**

“Then you could make a guideline book that you could have in your trouser pocket. I know, when I did my internship in Lund, there was this small guideline book, thin, which was very good.”
23 - Resident in General Surgery.

"It should not be more difficult than that you have an icon on the desktop, whether it is a link or if it is a program or whatever it is, it does not matter much, but you should sort of get straight to it… it should not be more than two keystrokes away."
3 - Resident in General Surgery.

Knowledge about guideline and where to find it **17/28**

"And I think many of the employees are too poorly versed in the guidelines. Both doctors and other healthcare professionals about which guidelines we have."
14 - Resident in Emergency Medicine.

Finding the right among many **6/28**

When you check up on guidelines, it sometimes comes up things like "Central venous catheter". That there can be such strange things that are not at all what you want to find. You want to get to the medically specific guidelines, and it is very difficult. So, there should only be one direct link there."
11 - Intern.

Trust in the guideline **22/28**

Collective perception **13/28**

"And the person who has written our local guideline is very up to date in the research, so I completely trust his judgment."
14 - Resident in Emergency Medicine.

"Because there have been some errors in our guideline book that they have had to correct afterward. There may be on Internedmedicin.se as well, I know nothing about that, but there are more people who read it daily, and I think it has been examined even harder because it is so publicly available"
8 - Intern.

Scientific evidence **14/28**

"It is not always the case that the guideline is updated every six months and research is progressing fairly quickly in many areas. So, the absolute newest or latest recommendation for investigation and management of syndrome X may not have had time to diffuse into our local guideline."
9 - Resident in Emergency Medicine.

Workload **27/28**

Subjective stress **15/28**

"When you get stressed you become a little more primitive, you go into your inner self, you solve problems, and you do what you think is best and go more on gut feeling."
21 - Intern.

"I almost think that it [stress] makes you use it [guidelines] more because if there is a lot that bothers and interrupts, you think a little worse."
4 - Resident in Emergency Medicine.

Work environment **15/28**

"It sometimes happens, when there are a lot of patients that seek care, that we can get a shortage of nurses who can take this test which has a limit of six hours. I would probably say that it may be a reason to do a CT then because we also have a lack of beds. We cannot admit and observe them for twelve hours in a simple way."
16 - Specialist in Emergency Medicine.

Amount of time at disposal **13/28**

"No, I do not sit and look for a guideline that I cannot find in half an hour. Instead, I can take the next patient."
15 - Resident in Emergency Medicine.

Culture	28/28
Attitude among staff	**25/28**
"The nurses are well acquainted with it, so often even before we meet the patient, they have taken a history of the patient and asked how long it has been since the head injury and if they are on anticoagulation. And then they come and ask us if we want to order an S100B." # 14 - Resident in Emergency Medicine. "The nurses or assistant nurses believe that the patients should be managed in a certain way. They often want things to flow on and go fast and so on." # 12 - Resident in General Surgery	
Leadership	**23/28**
"On the other hand, it has happened that I have wanted to treat the patient according to our local guideline, but the person I consult with wants to do something else. But then it's on them." # 7 - Intern.	

Patient-related factors	24/28
Incompatibility between patient and guideline	**20/28**
"So, it is me who sees the patient in front of me, it is not our guideline that sees it. So, if I think it is wrong, I will do it my way." # 15 - Resident in Emergency Medicine.	
Complexity in the individual case	**11/28**
"Then there are always patients who are… it is difficult to really put your finger on what is the cause of seeking care or what is the triggering problem and then you cannot turn to specific guidelines, because… Yes, if the symptoms go together and it is not really clear, then you do not know which guideline to choose." # 7 - Intern. "While a local guideline is often based on the patient having a medical condition. But if the patient has more than one condition that you have to weigh in, you may sometimes need to make an intermediate solution, which means that you have not fully followed the local guideline, which can sometimes make it a little difficult." # 9 - Resident in Emergency Medicine.	

Doctor related factors	23/28
Individual doctor competence	**13/28**
"… There are those who temporarily work at the department who may need a local guideline and also older colleagues who have not encountered this for a long time, or… yes, also need a little… go back and check." # 11 - Intern.	
Experience	**13/28**
"Less experienced, new doctors, I think, use local guidelines in the best possible way. But an older, experienced person, a doctor, is probably able to tailor his patient management better than a local guideline." # 29 - Resident in Emergency Medicine.	
Convenience and ego	**8/28**
"If I have received a positive that I should x-ray the neck and the patient has a small cut in the forehead, then I usually have a fairly low threshold to x-ray the head as well." # 9 - Resident in Emergency Medicine. "If you feel that you would not want to follow it [local guideline], there can be quite a lot of problems if a problem or complication should arise later. And if you have not followed the local guideline, many will be afraid of it as well." # 28 - Resident in Emergency Medicine.	

Thoughts on the local TBI guideline

The local TBI guideline was regarded as distinct by a majority of the interviewees. The trauma-energy level required for inclusion was uncertain for some interviewees, a common situation being a patient that presents with a trivial trauma but with risk factors present that mandate a CT-scan according to the guideline.

> *"There is nothing about how severe the head trauma needs to be. If you walk into a lamppost, does it count as a sufficiently serious trauma to justify a CT just because you are over 65 and are under treatment with a platelet aggregation inhibitor?"*
>
> #2 – Resident in General Surgery.

Mandatory hospital admission for observation for patients under treatment with anticoagulants with a normal head CT-scan was viewed by a few as exaggerated.

> *"The care might be a bit exaggerated, especially for those with a minimal head injury and ongoing anticoagulation. If you then have to follow it [local guideline], it will be a lot of CT, a lot of hospitalizations, and a lot of care."*
>
> #13 – Resident in Emergency Medicine.

The biomarker S100B was sometimes perceived as problematic. The cause for this was the long analysis times and the potential for false-positive results that would still mandate a CT but with significant delay.

> *"And you order an S100B that is false positive, which when I feel, can sometimes force you to do a CT on a patient when you really wanted not to do it, if it is a young patient, for example."*
>
> #14 – Resident in Emergency Medicine.

Patients presenting after 24 hours or under concurrent treatment with multiple platelet inhibitors were perceived by some to be missed by the current guideline. A few interviewees were uncertain about managing intoxicated patients and did not feel they received proper instructions regarding this in the guidelines. The distinction between different levels of TBI could be made more visually apparent.

"I think if I had done it, I would have made larger letters or capital letters where it says acetylsalicylic acid or anticoagulants so that when you look at it quickly, it is clear that 'Oh, here it was something different. Those patients should go into another category."

#9 – Resident in Emergency Medicine.

Methodological Considerations

Paper I

Practical difficulties

In order to standardize the review of the medical records, a coding manual was written before the start, but the manual was not detailed or specified enough to cover the wide range of answers in the medical records. The coding manual was not tested before implementation, and modulations that had to be done were done as they emerged.

Theoretical limitations

The way the study participants were included affected the ability to extrapolate the findings to other contexts and compare them to other studies. By including patients registered as "head injury" in the ED electronic patient registry (and excluding patients with multiple injuries) rather than specific ICD-10 codes, patients that not had a TBI could have been included (e.g., superficial lacerations, trivial trauma, or misclassification) as well as missing patients suffering a true TBI that was registered as "Multi trauma". Although the apparent misclassifications could be easily removed, the superficial and trivial injuries could not be excluded with the same ease and thus included. Some of the more severely injured patients, presumably with more severe TBI, were missed through our selection process. This selection bias affects the proportions of the various TBIs, with a very high proportion of minimal and mild injuries, and at least theoretically dilutes the cases of ICI, the need for neurosurgery, and death due to TBI.

The population in Helsingborg hospitals' catchment area is demographically diverse regarding both age, sex, and ethnicity. There is a mix of rural and urban areas, but a large metropolitan area is missing, potentially preventing generalizability to such areas. The population at risk (i.e., the population in the catchment area of Helsingborg hospital) was not estimated at the time of the study, but rather several years later through the relative change in population numbers between 2020 and 2021. There is an inherent risk of miscalculating the actual size of the population at risk, thereby the risk of over and understating the incidence of TBI.

The retrospective nature of this study prevents any firm conclusions from being drawn and should be viewed from the perspective of previous studies on the subject. Any findings need to be validated in a prospective setting. A systematic interpretation bias might have been introduced and impossible to correct for afterward. Using a second or third data collector would make the data less susceptible to interpretation bias, but a substantial inter-collector variability could have been introduced and disguised potential findings.

A coding manual during the data collection is essential in order to try to standardize the data collection process as much as possible. However, the collection is only as good as the document, and a poorly or wrongfully designed document could introduce a systematic bias that would be impossible to correct afterward. The same reasoning can be applied to replacing the missing data using the parameters' median. This method is not uncommon in statistical analysis but can risk skewing the data and introduce other systematic biases.

Potential improvements

The selection of patients could be improved by using specific ICD-10 codes rather than what the patient registered as in the ED to make the cohort more similar to those in other studies, enabling a better epidemiological comparison.

The coding manual needs to take into consideration the wide range of answers that can arise from trying to interpret non-standardized medical records and provide coding options for these or stipulate how ambiguous findings should be interpreted (e.g., if the patient is unsure about the loss of consciousness or it is not mentioned at all, how should it be interpreted?). Determination of inter-rater reliability through a suitable agreement analysis method could ensure that the coding manual is systematic.

Paper II

Practical difficulties

The practical difficulties were, to a lesser extent, similar to paper I. The coding manual was more thorough and also field-tested before start.

Theoretical limitations

The patients in paper II were, as in paper I, identified through the electronic patient registry in the ED, with the same drawbacks as previously written. The interpretation of retrospective medical records still posed a difficulty due to variable levels of documentation of the different parameters. However, the coding manual was more detailed and tested before the actual start and could amend this problem, at least partly.

Missing data regarding a parameter was interpreted as an absence of that specific parameter. This was deemed a reasonable approach since we collected parameters routinely asked and interpreted when managing a patient with TBI, but still poses a risk of understating the severity of the injury. The CCHR and NOC could only be applied to a minority, and this might in part be attributed to cases where the presence of loss of consciousness, amnesia, or disorientation was not documented, thus making the patient ineligible for inclusion.

The degree of consciousness was almost exclusively documented in RLS-85 and had to be converted to GCS. This is a necessary but sub-optimal solution, especially when no formal documentation of the degree of consciousness is documented but rather a more descriptive text is provided. This would generate a two-step interpretation process with the risk of bias. There is also no uniform or agreed-upon way to convert RLS-85 to GCS or vice versa. The greatest challenge is converting RLS 3 to a corresponding GCS-level, which encompasses GCS 9-13. An RLS-score of 1 is converted to GCS 15 since both correspond to an unaffected patient, and once a patient is unconscious, conversion is solely based on the motor response, which is the same between the two.

This study also used a single data collector, but unlike in paper I, an agreement analysis was performed using both Cohens' kappa and a percentage agreement. The varying values are due to the differences in how often each parameter was interpreted as positive. For example, treatment with low molecular-weight heparin showed poor Cohen's kappa but a high percentage agreement, indicating that a small number of different interpretations caused the considerable reduction. The majority of the parameters showed a good or a very good interrater agreement, and all but one had a percentage agreement over 90. Some parameters that, to a large extent, depended on personal interpretation showed only a fair or a moderate agreement. There is still a risk of systematic bias through inherent deficiencies in the coding manual, but this interrater agreement analysis validates the document and data collection in that it is consistent.

The concerns regarding the patient population are the same as in paper I since the population from which the patients came was the same. The population at risk was estimated in the same way as in paper I, with the same risks.

Potential improvements

A patient identification using ICD-10 codes instead of the patient registry in the ED would render a more representative cohort for comparing the different guidelines since patients that did not have a TBI (e.g., superficial lacerations) would be excluded and not dilute the factual findings.

Paper III

Practical difficulties

No significant practical difficulties were encountered. The coding manual used was designed before the start with the experiences from the previous coding manuals. It showed a good ability to encompass the different answers that could arise, and its' performance was satisfactory. Some updates were made to the document as coding proceeded, ensuring continued consistency in the interpretations throughout the entire data set.

Theoretical limitations

There was a large percentage of missing data regarding clinical findings, patient history, and ICIs' details. Not mentioning specific clinical findings and aspects from patient history were interpreted as an absence of said finding like in the previous paper. We believed this to represent how clinicians work in the ED, preferring to be succinct and not negate normal findings. The findings used to determine whether a patient could have been discharged or not were also almost exclusively findings that could be verified in either the medical records or radiology report (e.g., type of injury, use of blood thinners). The data could not be assumed to be missing at random, and using a multiple imputation model could bias the data.

The problem regarding using the RLS-85 instead of GCS was the same as in paper II and had to be converted. This posed a lesser problem than previous studies since the only important classification that had to be done when applying the guidelines was to determine whether a patient was RLS 1/GCS 15, a simple interpretation and conversion.

The fact that only 68.5% of cases mentioned the size of the intracranial hemorrhage was problematic since this parameter was paramount for determining whether a patient could have been discharged or not. A more significant proportion of these patients had subarachnoid hemorrhage than the rest of the cohort, a type of bleeding that is harder to measure and quantify when compared to other kinds of hemorrhages. The choice to interpret the size of the hemorrhage based on the radiological verdict poses a risk of classifying hemorrhages that are larger than the cut-off of five millimeters as smaller than five millimeters. However, this interpretation was made very conservatively to mitigate this.

The concerns regarding the patient population are the same as in paper I since the population from which the patients come is the same.

Potential improvements

A single person collected the data, and the reliability of the interpretations of medical records could have been increased through an agreement analysis.

Introducing a standardized radiology reporting form for ICIs could potentially reduce the amount of missing data regarding the size of the hemorrhage. A more feasible option would be to recruit a radiologist, preferably a neuroradiologist, to interpret the CT scans again and provide measurements of ICIs when they were missing.

Paper IV

Practical difficulties

Practical difficulties included acquiring a broad spectrum of participants from each of the predefined experience and sub-specialty categories. There were no specialists in general surgery participating in the study, and a relatively large proportion of participants were interns. The recruitment process was cumbersome, and several reminders had to be sent to multiple participants. It was also hard to accurately determine which participants fulfilled the inclusion criteria and investigate this personal contact had to be taken with several potential study participants.

Theoretical limitations

The qualitative approach is a suitable method for gaining deep knowledge and nuances regarding a population that is difficult to acquire through quantitative methods. However, the generalisability of the findings is much more uncertain. It is theoretically possible that the barriers and recommendations stated in the paper only are applicable in the ED at Helsingborg hospital. In a few years and with different physician staffing, the findings might not apply at Helsingborg hospital.

Many of the participants were colleagues to the lead author and thus knew about the research project and could thus have been inclined to state higher levels of guideline adherence or talk more positively about the local TBI guideline due to social pressure. The authors' previous knowledge about barriers for guideline adherence might also have affected which branching questions were chosen, which would be susceptible to confirmation and question order bias.

Potential improvements

Even though the interview questions were tested before the start, they still had to be rephrased in several additional interviews to convey what was asked. This made the questioning process less standardized and could have been improved through additional mock interviews before the actual interviews.

The interviews performed early sometimes contained leading questions, which could have been reduced.

Discussion

Current epidemiology of TBI

The first two papers in this dissertation demonstrate similar findings compared with previous studies regarding TBI epidemiology, the majority of the TBI victims are male, and the predominant mechanism of injury is falling. However, the median age in both studies is substantially higher than previous studies in Sweden conducted in 1992-1993 and 2001, adhering to the trend of increasing incidence amongst the elderly (21,22). Both papers still show a peak in ages around twenty years and a bimodal distribution regarding age, representing a still high incidence in young people. When comparing the distribution between different trauma mechanisms in paper II regarding age, many patients aged 18-29 were subjects to assaults or sports injuries. These two mechanisms were almost non-existent in patients aged 70-89, where falls from various heights constituted almost all cases.

None of the papers studied the incidence of TBI nor the total population at risk at the time of their writing. These were instead estimated several years later by assuming that the population in the catchment area grew linearly through these years. It is possible that the population from which the studied cases came from grew at different rates each year, especially since the migration crisis in 2015. This could have led to a more rapidly growing population in 2015 and the following years than expected. If this is the case, the population at risk in 2014 would have been smaller and thus have a higher incidence. This assumption could then, at least in part, explain the differences in incidence seen between 2014 and 2017.

These incidences are high when compared to several previous studies but not previously unseen. When looking at the incidence of hospitalization, it is slightly higher compared to the findings by Koskinen et al., and at the same time, much lower than what was shown by Majdan et al. The incidence of fatal TBI is much lower in our studies compared to both studies by Koskinen et al. and Majdan et al.(15,16,18,20–22,25,26,28,32). The difference in incidence can be attributed to the broad definition of TBI chosen for papers I and II, all patients registered as ”Head trauma” in the ED. This categorization includes both severe TBI and superficial lacerations in the head area. One is a TBI, while the other one is more ambiguous. This dilutes the actual TBI cases, but this approach was chosen to ensure that no patient was missed in the inclusion. Also, it can be hard to appreciate the clinician's situation when writing the note, thus potentially perceiving an injury as trivial while it was not.

The proportion of minimal- and mild traumatic brain injury was high in this material, most likely due to the systematic exclusion of patients suffering multi-system trauma. These patients would not be registered as head injuries, even though it might well have been their most serious injury and thus missed. It is reasonable to assume that these patients would have a higher proportion of moderate and severe TBI. It is also likely that they would die due to their TBI to a more considerable extent than those with isolated injuries, explaining the low incidence of fatal TBI compared to previous studies. Another uncertainty to take into account is also the fact that a significant minority of patients never seek medical attention for their head injury, and using the numbers (25% not seeking medical care) in the study by Sosin, Sniezek and Thurman, incidence could have been as high as 693.25/100,000 in 2014 and 730/100,000 in 2017. In that case, it is reasonable to assume that these extra injuries that are unaccounted for would consist of minimal and mild injuries, skewing the distributions even further.

Determining trauma energy level

The trauma energy level is a factor considered in both the CCHR and NICE guidelines, recommending a CT scan when specific trauma mechanisms have occurred. Mechanism of injury is an independent predictor of outcome after blunt injury and associated with the need for specialized care and interventions in general. It is currently a part of national and local triage algorithms for prehospital emergency medical services in deciding whether a patient needs transport to a trauma center or if a trauma team should be alerted before arrival (49,60,112–115).

However, studies show conflicting results regarding the significance of specific trauma mechanisms in predicting significant injury, and the rationale for using the trauma mechanism as a basis for clinical decisions in the absence of objective findings has been questioned. One study shows no specific predictive value in the mechanism of injury in the absence of signs of significant injury or physiological derangement. In contrast, another study showed increased odds for having a severe injury, dying, or requiring an urgent intervention solely based on the mechanism of injury. An evaluation of the most recent changes in criteria for trauma team activation in Sweden showed that more restrictive criteria regarding the mechanism of injury led to fewer trauma team activations with maintained patient safety(116–120).

Blunt, high energy trauma is often defined per the mechanism triage criteria according to the ATLS®, and anything below this would constitute low energy trauma(114). In paper I, we narrowed the definition for low-energy trauma to include only falls from less than one meter and less serious blows from external objects to make the group "low-energy trauma" more manageable and distinguishable from higher energy traumas not fulfilling high energy criteria. We found that the vast majority of patients, despite this narrowing, fulfilled the criteria of low energy trauma. Based on our findings in paper I, we speculated that patients under 59 years of age, without any blood thinners and that suffered low energy trauma, could potentially be discharged from the ED based on these findings alone.

These findings were contradicted by another study based on the cohort in paper II, where eight patients had intracranial hemorrhage despite fulfilling the previously mentioned criteria(121). Low elevation falls can be heterogeneous in actual energy delivered to the head upon impact, depending on the surface on which the fall occurred and if the patient managed to break the fall with another body part before impact. A fall on the grass where the patient managed to break the fall with an arm before hitting the head is substantially different from a high-speed slipping on concrete without breaking the fall, yet both would be classified as ground-level fall and thus "low-energy trauma". Low-level falls constitute a large proportion of trauma-related mortality, especially among the elderly with previous medical conditions, but are also a significant cause of serious injury in non-elderly patients(122–125).

Stratifying trauma energy levels can be problematic in TBI since it is not uncommon with amnesia, intoxication, or varying levels of dementia in elderly patients. Rigid criteria for management based on patient history risk leading the clinician astray, either over or underutilizing CT scanning. The fact that low-energy trauma mechanisms often can be associated with significant injuries even among younger people makes these criteria even harder to use. Relying on more objective measures to stratify the risk of ICI, such as objective clinical findings or biomarkers(126), seems more appropriate than relying on an often-vague history trying to describe the mechanism of injury in detail.

Guideline adherence

Guidelines are developed to help physicians make better clinical decisions and to narrow the gap between best evidence and current practice. Despite this ambition, guideline adherence is often low and variable in many areas of medicine and leaves room for increased guideline adherence(127–129).

General factors affecting guideline adherence

Barriers and facilitators for guideline adherence have been investigated in several different areas of medicine. An interview study done by Sinuff et al. in 2007 looked at barriers for guideline adherence in the ICU and found them often related to external factors (workload, a large number of guidelines to keep track of, or complex and severe illness), but also barriers inherent to specific guidelines (complex guidelines, time- and labor-intensive tasks recommended) and lack of an encouraging culture (inconsistent adherence). These barriers are very consistent with the barriers we found in our interview study amongst ED physicians, not that surprising perhaps since these environments have several common denominators. Both are dealing with very ill (or potentially very ill) patients, often several at once, with a wide variety of potential conditions with often complex treatments and workups.

Their proposed facilitators focused on establishing a strong local culture, including people working “on the floor” and higher up in the management hierarchy. The guideline format had to be simple, developed with all critical users involved. The guideline had to be accessible quickly at the point of care to remind the busy clinician. There had to be regular audits of patient care to measure current guideline adherence and how it has changed, both on group level and of individual caregivers. Dedicated education time with education tailored to the different needs of the learners was also deemed necessary (130). Like the previously mentioned barriers, several facilitators were in line with what was concluded in paper IV.

Similar findings regarding barriers and facilitators were reported by Westafer et al. in 2020 when interviewing physicians regarding the use of risk stratification tools in the evaluation of pulmonary embolism in the ED. They reported barriers primarily on a guideline level, with skepticism towards certain parts of the tool or the tool is too complex, but also brought forward lack of knowledge of guideline existence or not having a distinct way to keep updated with the latest findings. Their facilitators also included institutional support and a straightforward, easy-to-follow algorithm that was readily available. They also mentioned individual performance audits and education around the proper use of risk stratification tools(131).

A bit contrary to the conclusion in these two studies regarding the necessity of audit feedback and continued education is a study by Frazier et al., reporting on ways to reduce chest x-rays in pediatric patients with bronchiolitis. They found no benefit of educational campaigns or audit feedback. However, They could instead show a pretty dramatic reduction (42.1% to 18.9%) through removing chest x-ray as a default option in their order set for patients with dyspnea and introduce reminders of recommended best practices in the electronic medical records for all patients with a charted diagnosis of bronchiolitis(132).

Similar recommendations were made by Kawamoto et al. in 2005 in a systematic review of features of clinical decision support systems (defined as any system considering specific patient characteristics and then providing either an assessment or recommendation for the physician to consider), where they concluded that

> "On a practical level, our findings imply that clinicians should implement clinical decision support systems that (a) provide decision support automatically as part of clinician workflow, (b) deliver decision support at the time and location of decision making, (c) provide actionable recommendations, and (d) use a computer to generate the decision support As a general principle our findings suggest that an effective clinical decision support system must minimise the effort required by clinicians to receive and act on system recommendations."

Introduction of such a clinical decision support system when ordering a CT in mTBI significantly increased the proportion of CT scans correctly ordered according to a guideline(133,134).

Another aspect that could contribute to guideline adherence is that it takes time for a newly introduced guideline to disseminate among the people using it, and guideline adherence is measured right after it is introduced it is only expected that adherence is low even though the users agree with and have a positive attitude towards it.

Heskestad et al. conducted two studies regarding adherence to the SNC guideline at a tertiary hospital in Norway in 2003-2004 and the first half of 2005, 2007, and 2009. The first study showed a modest adherence of 51% with a significant over-triage among minimally injured patients. The only intervention was the announcement of the previous studies' results, yet guideline adherence increased to 63% (135,136). A questionnaire study conducted at our ED showed similar results, with a drop in guideline adherence from 60% to 40% after introduction(137). In an identical survey conducted four years later, guideline adherence had increased to 60% once again without specific interventions(not published). One can also speculate that the increase in CT use for mTBI in both the intervention and control hospitals that was noticed by Stiell et al. after trying to implement the CCHR could be attributable to a "passive" adoption of the CCHR and the passage of time at the control hospitals(138).

Guideline adherence for mTBI

In mTBI, adherence to various guidelines has been variable, with rates between 51-100% depending on study location and which guideline was studied. Rates between approximately 65-80% were the most frequently observed, and the non-adherence primarily consisted of over triage(135,136,138–145). Reported reasons for non-adherence were the belief that every traumatic finding needed to be documented, that performing CT scans had become the local standard, that CT scanning would lead to more reasonable care, and that there were no consequences when circumventing the rule(138). Another study revealed that physicians sometimes stated that every patient is unique and extracranial injuries as reasons for not adhering to a guideline (146).

Several studies have looked at the rate of guideline adherence among pediatric and adult patients with severe TBI and shown improved outcomes with higher levels of adherence at no increased costs compared to not following a guideline. The introduction of clinical decision support systems when ordering specific radiological examinations (such as a head CT after minor head trauma) might have contributed to a decline in the use of CT, and a questionnaire study performed at our institution showed higher levels of CT utilization in patients with mTBI when a CDR was not used (60% vs. 51%)(137,147–150).

A living systematic review done by Cnossen et al. looked at several studies evaluating guideline adherence in TBI management. They found that guidelines containing strong recommendations were more likely to be adhered to, as well as guidelines with less invasive interventions (e.g., CT = Less invasive, Craniotomy = More invasive)(151).

Drawbacks of implementation and adherence to CDRs

A central question when discussing adherence to CDRs is whether 100% adherence is desirable. This is a complex question, and the answer indeed is different depending on clinical specialty and context. A study on the 5-year survival of patients with breast cancer in Germany showed that survival increased over time in patients not managed according to guidelines(152). The proposed reason for this finding was that treatment might have been tailored to the individual rather than using a cookie-cutter approach. A similar example was seen in a study by Easter et al. that looked at sensitivity and specificity for three commons CDRs for pediatric head injury and compared their performance to detect clinically important ICI to physicians' judgment. Physicians' estimation had an area under the curve exceeding that of all the studied guidelines, and the actual physician practice achieved a 100% sensitivity for clinically important ICI along with only one of the studied guidelines(153). However, it is noteworthy that the physicians who made the estimations were attendings, and the result might thus not be directly applied to more junior doctors, the leading staffing group in many EDs'.

Many of the big CDRs for mTBI were developed to safely reduce the amount of CT scans in a time and place where a CT scan of the head was the norm. A bit paradoxically, the introduction of mTBI guidelines can sometimes increase the CT rate, as demonstrated by two studies trying to implement the CCHR (138,154). The same is potentially valid for pediatric TBI, where an introduction of any of the three most studied CDRs likely would lead to a dramatic increase in the number of CT scans performed for minor head injuries (155).

Benefits and hazards of doing less CT and admitting fewer

Whether or not CDRs for mTBI increase or decrease the rate of CT depends on the current practice where the CDR is to be introduced. The findings in paper II suggest that broad adoption of either the SNC or the NICE guideline would lead to a significant reduction in CT rate after mTBI, at the expense of missing some intracranial injuries without the need for intervention. In that context, it is not far-fetched to ask, do we need to identify all cases of ICI? Already when developing the CCHR in 2001, some injuries were deemed “clinically unimportant”, not needing admission nor specialized follow-up, and a clear emphasis was put on identifying (49). A similar definition in the context of pediatric TBI was made by Nigrovic et al., where specific criteria had to be met for an injury to be clinically important(156). Even though not explicitly stated in the article, other injuries could therefore be interpreted as clinically unimportant.

Effects of reduced CT rate

A head CT in Sweden in 2021 costs between approximately 900 to 1250 Swedish crowns, or US$105 to US$145 (157,158). Using these numbers, rigorously adhering to the SNC guidelines could lead to savings of 109,800-152,500 Swedish crowns (US$12,840 – US$17,835) per year at Helsingborg hospital. If the NICE guide had been used in the same manner, the potential savings would have been 207,000-287,000 Swedish crowns (US$24,225-US$33,587) per year at Helsingborg hospital. In a time of increasing economic strain upon the health care system, these expenditures could do better elsewhere.

Another aspect is the patients’ exposure to ionizing radiation that accompanies a head CT. One in 8,100 women who go through a routine head CT at age 40 is estimated to later develop a malignancy due to that CT, with approximately double the risk done at age 20(159). Since the incidence of mTBI is high and the proportion of young patients suffering from it, the radiation exposure on a population level can lead to a significant number of malignancies.

There seem to be many reasons to reduce the amount of CT scans as possible with maintained safety. However, since no CDR is 100% sensitive all the time for all types of ICIs', a reduction in CT rate will undoubtedly lead to missed cases. It is possible (and often likely) that a minor injury visible on an initial CT will not lead to any actual change in the patient's management, except for an uneventful night observation at the hospital.

However, it is worth noticing that the presence of ICI increases the risk of unplanned revisits to the ED and developing persistent, post-traumatic headaches (160–162). Post-traumatic headache is often a part of the post-concussive syndrome along with dizziness, neurocognitive impairment, and intolerance to various sensory stimuli, sometimes for a very long time(163). This condition is debilitating for people that suffer from it but can be treated if identified(164,165). While patients who develop post-concussive syndrome are not identified in the ED on their initial presentation, knowledge about the presence of an ICI can potentially prime both the patient and physicians to be more alert for possible post-concussive symptoms and initiate treatment early if it occurs.

This dissertation in a larger context and ideas for the future

The studies on which this dissertation is based have provided a recent review of the epidemiology of patients with head trauma, an essential part of monitoring epidemiological trends over time and reevaluating the usability of previously developed guidelines. A new review of the TBI epidemiology in the area can be motivated to determine if the age distribution, sex difference, and most common type of trauma mechanism are still changing within the next five to ten years.

A selection of international CDRs for managing patients with mTBI has, for the first time, been compared to one another in the same cohort, showing results indicating that these patients can be managed using fewer CT scans. This would lead to fewer radiation-induced malignancies, lower healthcare expenditures, and shorter lengths of stay in the ED. Furthermore, for the patients who get scanned and have ICI, some might be discharged from the ED instead of admitted, further decreasing health care expenditures, and freeing up hospital beds for patients in more dire need. The next logical step to take if the adoption of these rules were to take place is to conduct a prospective, multi-center trial to determine the safety of each guideline and their potential reduction in admissions for ICI.

The information regarding improving guideline adherence in the ED could help produce guidelines more suited for people working in such a diverse environment as an ED is. This will, in turn, lead to higher levels of guideline adherence, with the previously mentioned benefits for both the patients and the healthcare system. The result of the proposed interventions stated in paper IV can be evaluated with a repeat interview study, preferably with the subjects involved in the initial study, or with a questionnaire study like the one previously performed at the study site to measure guideline adherence(137).

Conclusions

- The epidemiology of patients presenting with head trauma at Helsingborg hospital is consistent with the epidemiology of TBI patients in most other western countries, with continued male dominance, increased patient age, and falling as the primary mechanism of injury. Increasing age, mTBI as the degree of head injury, new onset of neurological deficits, and low-energy trauma mechanism was associated with the presence of intracranial hemorrhages.

- Adopting either the SNC or NICE guideline when managing patients with mTBI could lead to a safe reduction in CT rate without missing any injuries requiring intervention. The SNC would lead to a 9% reduction, and NICE would lead to a 17% reduction in CT scans, respectively. All other evaluated guidelines would lead to an increase in CT scanning.

- A small proportion of patients with mTBI and concomitant ICI seem eligible for safe discharge from the ED without risk for adverse events as per either BIG or mTBI-RS. The proportion of patients eligible for discharge was smaller compared to both guidelines' original studies.

- Barriers to guideline adherence in the ED were centered on low accessibility and poorly designed guideline documents. Facilitators for guideline adherence were centered around concise guideline documents, well-designed visual aids, high accessibility, and encouragement from peers and management. To improve the local TBI guideline, the inclusion of patients and clinical situations currently not addressed should be evaluated further.

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