CHAPTER 1

General introduction

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Traumatic Brain Injury (TBI) is a major health and socio-economic problem worldwide. Although society is largely unaware of the magnitude of the problem, TBI is a growing epidemic.[1,2] Each year over 50 million people will have a TBI and it is estimated that approximately 50% of the world's population will have at least one TBI in their lifetime. TBI is a leading cause of mortality and disability in all age groups, for young adults it is even the leading injury-related cause of death. Not only the health impact of TBI is huge, also the economic impact is substantial. An estimate of total costs of TBI for the global economy is about US$ 400billion annually, which is approximately 0.5% of the entire global output.[3,4]

TBI severity classification

Fortunately, not all head trauma leads to TBI. Only patients with head trauma *and* evidence of brain pathology are classified as TBI.[5] The exact percentage of patients with head trauma that have TBI is unknown because many individuals with head injury do not seek medical care.

The Glasgow Coma Scale (GCS) is the most widely used score to classify the severity of TBI. The GCS was originally published in 1974 to objectively describe the extent of impaired consciousness.[6] Nowadays the GCS is, in combination with other factors, also used to assess TBI severity. However, the GCS has some limitations, mainly because other factors such as alcohol intoxication may alter consciousness regardless of TBI.

Based on GCS on arrival at hospital TBI is classified as follows:[7]

- Mild TBI: GCS 13-15; mortality ~ 0.2-0.4%
- Moderate TBI: GCS 9-12; mortality ~ 10%
- Severe TBI: GCS 3-8; mortality ~ 40%

The vast majority of TBI can be classified as mild TBI and this thesis will mainly focus on that group. However, this is actually a misnomer because a substantial part of patients with mild TBI still have complaints 6-12 months after the trauma, moreover some (0.2-0.4%) individuals even die as a result of 'mild' TBI.[8-11]

Epidemiology

The incidence of TBI is rising globally, both in low- and middle-income countries and in high income countries.[1,3] Although rough estimates of the incidence of TBI exist, the exact incidence is unknown.[1] Causes of uncertainty and poor comparability

of incidence estimates are various. First, many individuals with mild TBI probably do not seek medical help and may not be registered as such. Second, definitions of TBI and head trauma are subject of debate and different definitions are used in different registries, complicating international use and comparison. Third, the source of information may cause substantial variation in incidence estimates. Sources of information can be either routinely registered information, such as International Classification of Disease (ICD) codes, or specifically collected data such as national trauma registries, which may result in differences in estimates.

The incidence of TBI is not only rising, the epidemiology of TBI is also changing. A distinction has to be made between low- and middle-income countries and high-income countries. Globally, two leading causes of TBI can be identified: motor vehicle accidents and falls. In low- and middle- income countries motor vehicle accidents are the leading cause of TBI and the increasing use of motorized vehicles in combination with poor road safety leads to more TBI.[3,12] In contrast, in high income countries, with an ageing population and increased road safety, falls are the main cause of TBI nowadays.[13-15] For example in the USA falls are the leading cause of TBI-related emergency department (ED) visits (48% in 2014) and hospitalizations (52% in 2014). However, in the USA intentional self-harm (33% in 2014, mostly due to fire arms) followed by falls (28% in 2014) were the overall leading causes of death from TBI.[2,16]

Guidelines for diagnostics

The large majority of individuals with head injury have no intracranial complications and many do not even need professional care. Nonetheless, a small but important group does have traumatic (intra)cranial lesions and these lesions can lead to severe disability or even death. The most used technique to reliably rule out (intra)cranial lesions is head computed tomography (CT), which is available in all Dutch hospitals. However, there are important disadvantages of scanning all patients with head injury. First and most important, scanning all patients with head trauma would lead to many more ED visits and prolonged ED throughput times and crowding as result.[17] Second, CT scanning exposes the patient to (a limited) radiation risk.[18,19] Third, the price of CT varies substantially and can be up to US$2200 for a non-contrast head CT.[19,20] Therefore, CT should be used selectively for those patients that benefit most and several guidelines have been developed for this purpose. Globally, the guidelines that are most widely used are the Canadian CT Head Rule (CCHR) and the New Orleans Criteria (NOC).[21,22] These guidelines are suitable for patients with mild traumatic brain injury that have loss of consciousness, amnesia or confusion. However, many patients with head trauma do not have any of these and are still at risk for (intra) cranial lesions.[23,24] Therefore the CT in Head Injury Patients (CHIP) decision rule

was developed in the Netherlands.[25] The CHIP decision rule is applicable for almost all patients with head injury and a GCS between 13 and 15. However, until the study included in this thesis, the CHIP had not been externally validated.

The Dutch situation

In the Netherlands the general practitioner is traditionally the gatekeeper for secondary healthcare and is available 24/7. However, in emergency situations patients can come directly to the ED or (in more serious situations) call the national emergency number '112'. For head trauma, as for many other conditions, there is a grey area which patient should call 112, who should come to the ED, who should go to the general practitioner and who does not need any medical care. Some EDs have a joint triage with the out-of-hours general practitioners service. The triage determines which patients should be seen in the ED or by the general practitioner. This thesis will focus on ED care for patients with head injury.

In the ED patients with (minor) head trauma can, depending on local agreements, be treated by either emergency physicians or neurologists or residents of other specialties.

The Dutch guideline for minor head injury (MHI) was introduced in 2010 and partially revised in 2017.[26-28] According to the current Dutch guideline, minor head injury is defined as:

Head injury is any trauma to the head, other than superficial injuries to the face. For minor head injury the following criteria apply:

- *GCS at first examination 13-15*
- *In case of loss of consciousness: no more than 30 minutes*
- *In case of posttraumatic amnesia: no more than 24 hours*

The guideline formulated criteria for adults and children with minor head injury regarding: referral to a hospital; examination at the ED; performance of a CT; and admission to a hospital. Regarding indications for CT scanning in MHI, the guideline is with some adjustments based on the CHIP decision rule. The guideline has major and minor criteria for a head CT. In case of at least 1 major or 2 minor criteria a CT-scan of the head is indicated.

In the 2017 update antiplatelet therapy was added as a major risk factor and criteria for minimal head injury were formulated, for which a CT scan is, under circumstances, *not* indicated.[26]

Table 1. The Dutch guideline for CT scanning following MHI in adults

Major criteria	Minor Criteria
Pedestrian or cyclist versus vehicle	Fall from any elevation
Ejected from vehicle	Posttraumatic amnesia 2-4 hours
Vomiting	Visible injury to the head, excluding the face (without signs of fracture)
Posttraumatic amnesia (PTA) ≥ 4h	Loss of consciousness
Clinical signs of skull(base) fracture	GCS deterioration of 1 point (1 hour after presentation)
GCS < 15 on presentation (including persisting PTA)	Age ≥ 40
GCS deterioration ≥ 2 points (1 hour after presentation)	
Use of anticoagulants*	
Posttraumatic seizure	
Focal neurologic deficit	
Suspicion of intracranial injury after focal "high impact" injury	

*In 2017 antiplatelet therapy, other than acetylsalicylic acid monotherapy, was added as a major risk factor.

After introduction of the guideline in 2010 the authors expected a decrease in the number of CTs with approximately 30%.[27] However, several healthcare professionals feared that the guideline would lead to more rather than less diagnostics and referrals.[29-31] The evaluation of the guideline was the starting point of this thesis. We performed a simple 'before-after' study and concluded that the number of CTs increased in our hospital after the introduction of the guideline.[32] An extended version of that study has been included in this thesis in chapter 3. Another Dutch study that was subsequently published confirmed the conclusion of our before-after study: "The number of CTs performed for head trauma gradually increased over two decades, while the yield decreased. In 2011, despite implementation of a guideline aiming to improve selective use of CT in minor head injury, utilization significantly increased."[33]

Aim of the thesis

This thesis aims to study changing trends, risk factors, preventive measures and decision rules for diagnostics in patients with head trauma and TBI in emergency departments in the Netherlands.

Outline of the thesis

Part I Changing trends in traumatic brain injury

In **Chapter 2** epidemiological changes in TBI related ED visits, hospitalizations and mortality in the Netherlands are assessed. The results are put into context of the ageing population and increased traffic safety. In **Chapter 3** the association between implementation of the minor head injury guideline in 2010 and CT and hospital admission rate is described.

Part II Prevention of- and risk factors for traumatic brain injury

Chapter 4 reviews the association between the pre-injury use of antiplatelet therapy and traumatic intracranial hemorrhage. The association between the use of bicycle helmets and (prevention of) traumatic brain injury in the Netherlands is presented in **Chapter 5**.

Part III Decision rules for patients with minor head injury and mild traumatic brain injury

In **Chapter 6** several decision rules for minor head injury are validated and compared in a multicenter study in the Netherlands. The evaluated decision rules are the CHIP-rule, the NOC, the CCHR and the National Institute for Health and Care Excellence (NICE) clinical guideline for head injury. **Chapter 7** describes a possible adjustment of the CHIP-rule. This update aims to improve the identification of patients that require a head CT to identify traumatic lesions.

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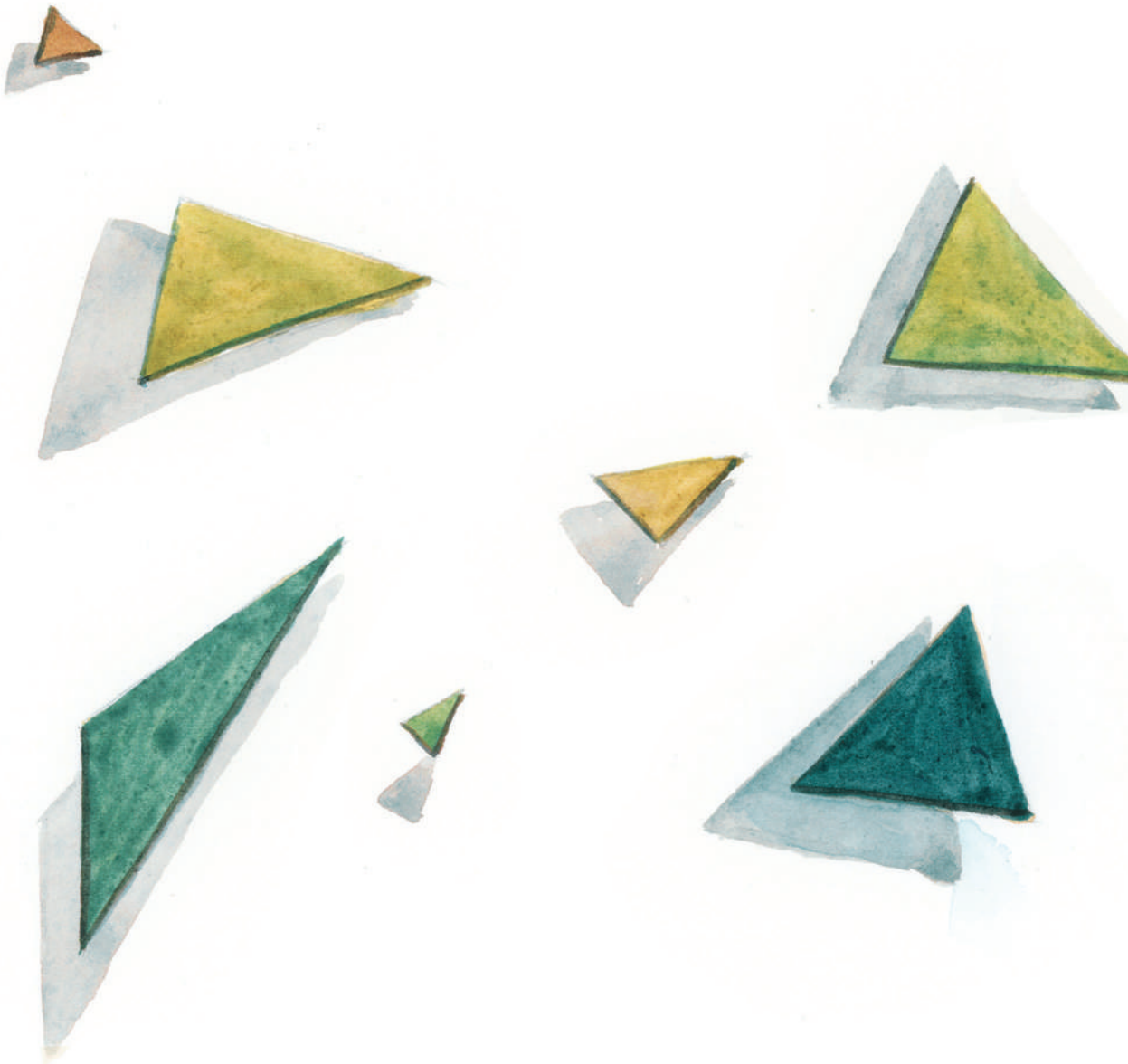

PART I

Changing trends in traumatic brain injury