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Head CT after minimal, mild and moderate traumatic brain injury; audit of clinical practice

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Abstract

Introduction: Traumatic brain injury (TBI), commonly classified as minimal, mild, moderate and severe, is one of the most common presentations in an Emergency Department (ED). Majority of TBIs are classified as minimal and mild, where 8-15% of the patients have a neurocranial injury (NI), and less than 1% requires neurosurgery. Guidelines have been developed in order to aid in the management of TBI patients, where the Scandinavian (SNC) guidelines for the management of TBI patients is standard practice at the Oslo Emergency Department (OED). However, it is evident in the literature that it is difficult to identify the small portion of patients at risk, which often leads to unnecessary head CTs. Further, recent studies describe a shift in the age and injury mechanism in the TBI population; we hypothesize that this trend is also reflected in the TBI population at OED. The aim of this study is two-fold; firstly, we will review the TBI population at OED as a cohort. To do this we will assess the frequency of TBI patients, describe patient characteristics, and the number of patients with NI. Secondly, we will assess compliance with the SNC guidelines at the OED.

Methods: Data was collected retrospectively of all consecutive head CTs preformed due to TBI at OED, between Jan-June 2016. It was gathered from the CT referral forms and radiology reports. Patient demographics as well as GCS-score, injury mechanism, anticoagulants, SNC guideline defined risk factors, symptoms and frequency of positive CT findings (NI) was retrieved. Guideline compliance regarding CT use was assessed, where compliant implied correct use of CT, and where no indication for a CT was found implied non-compliance.

Result: 2000 head CTs were performed during the study period, median age was 54 years and falls was the dominating trauma mechanism (69.4%). A positive head CT was described in 5.5% of the patients, where 0.25% required neurosurgical intervention. GCS-score of 14-15 and confirmed loss of consciousness was associated with a positive head CT ($p<0.05$). Compliance with the guidelines was seen in 88.2% whilst 11.8% resulted in non-compliance; correct application of the SNC guidelines would result in 13.4% reduction of head CTs.

Conclusion: Analysis of the TBI population at the OED confirmed the shift of an increase in age and falls being the most important trauma mechanism for minimal, mild and moderate TBI. Although guideline compliance rate was adequate, the high numbers of head CTs preformed is rather alarming. The lack of clinical risk factors present in the patients with a positive head CT highlights the need for constant revision of guidelines in this heterogeneous TBI population.

Sammendrag

Bakgrunn og formål: Traumatisk hodeskade, som hovedsakelig klassifiseres som minimal, lett, moderat og alvorlig, er en av de vanligste årsakene til å oppsøke legevakten. Minimale og lette hodeskader har høyest forekomst, hvor omlag 8-15% har en nevrokraniell skade (NKS) og mindre enn 1% krever nevrokirurgisk intervensjon. Det er utarbeidet en rekke retningslinjer for håndtering av hodeskadepasienter, hvor pasienter ved Oslo legevakt (OL) vurderes i henhold til de Skandinaviske retningslinjene (SR). Derimot viser litteraturen at det er utfordrende å identifisere de få tilfellene med økt risiko for NKS, som fører til en stor andel unødvendige CT caput undersøkelser. Videre viser studier en endring i alder og traumemekanisme blant hodeskadepasienter; vi hypotiserer at denne endringen også gjenspeiles i hodeskadepasienter ved OL. Formålet med denne studien er to-delt; først, evaluere hodeskadepasienter i form av en kohortstudie. Dette vil vi gjøre ved å vurdere andelen av hodeskadepasienter, beskrive pasientkarakteristikk, samt andel pasienter med NKS. Videre vil vi vurdere etterlevelse av SR ved OL

Metode: Data ble retrospektivt innhentet for alle CT caput undersøkelser etter hodeskader ved OL, i perioden Januar-Juni 2016. CT henvisning og radiologisk beskrivelse ble benyttet for datainnsamling, og inkluderte demografi, GCS-skår, traumemekanisme, blodfortynnende medikamenter, risikofaktorer definert av SR, kliniske symptomer og andel positiv CT caput undersøkelser (NKS). Etterlevelse av SR i forhold til bruk av CT caput ble vurdert, hvor korrekt bruk indikerte etterlevelse, og ikke-indisert CT caput indikerte manglende etterlevelse av SR.

Resultat: 2000 CT caput undersøkelser ble utført i løpet av studieperioden, median alder var 54 år og fall var den dominerende traumemekanismen (69.4%). Forekomst av positiv CT caput var rapportert i 5.5% av tilfellene, hvorav 0.25% krevde nevrokirurgisk intervensjon. GCS 14-15 og bekreftet bevissthetstap var assosiert med positiv CT caput ($p<0.05$). Korrekt etterlevelse av SR ble rapportert i 88.2% av undersøkelsene derimot var det manglende etterlevelse i 11.8% av tilfellene; korrekt bruk av SR ville resultert i 13.4% reduksjon av CT caput undersøkelsene.

Konklusjon: Analyse av hodeskadepasienter ved OL bekreftet økt alder og fall som den ledende traumemakanismen for minimale, lette og moderate hodeskader. Dog etterlevelsen av retningslinjene var adekvat, er antall CT caput undersøkelser urovekkende. Manglende risikofaktorer blant pasienter med positiv CT, framhever behovet for stadig revidering av retningslinjer ved denne heterogene pasientgruppen.

Abbreviations

ACEP	American College of Emergency Physicians
CCHR	Canadian CT Head Rule
CDC	Centers for Disease Control and Prevention
CENTER-TBI	Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury
CHIP	CT in Head Injury Patients
CT	Computerized Tomography
DAI	Diffuse axonal injury
DPO	Data Protection Officer
EDH	Epidural hematoma
EHR	Electronic health record
GCS	Glasgow Coma Scale
HISS	Head Injury Severity Scale
ICP	Intracranial pressure
ICD	International Classification of Diseases
IQR	Interquartile range
LOC	Loss of consciousness
MRI	Magnetic resonance imaging
NICE	National Institute for Health and Care Excellence
NOC	New Orleans Criteria
OED	Oslo Emergency Department
OUS	Oslo University Hospital
RIS	Radiology Information System
REC	Regional Ethical Committee
RTA	Road traffic accidents
S100B	S100 calcium binding protein B
SDH	Subdural hematoma
SNC	Scandinavian Neurotrauma Committee
SPSS	Statistical Package for Social Sciences
TBI	Traumatic brain injury
t-SAH	Traumatic subarachnoid hemorrhage
WHO	World Health Organization

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1.0 Introduction

1.1 Epidemiology of traumatic brain injury

Traumatic brain injury (TBI) is considered to be an important global health priority and represents one of the greatest contributors to death and disability among all trauma-related injuries. TBI is commonly referred to as an alteration in brain function, or other evidence of brain pathology, caused by an external force (1). The World Health Organization (WHO) estimates that almost 90 % of deaths are trauma related in low-and middle-income countries. Across all ages, TBI is one of the main causes of trauma-related deaths, and the leading cause of disability under forty-year-old's (2). Consequently, it is recognized as a major socioeconomic problem throughout the world, where the injuries are not only causing health-loss and disability for individuals and their families, but also contributes to an increased burden on the health-care systems due to high health-care costs (3). The direct and indirect costs of TBI in the USA have been estimated to be $ 75 billion (4).

TBI is a complex injury and varies in severity, ranging from minimal TBI (which also includes concussion) to severe TBI with potentially life-threatening brain damage (1). Globally, the total incidence of TBI is estimated at 939 cases per 100,000 people, which implies that sixty-nine million (95% CI 64-74 million) individuals will potentially suffer from TBI each year. However, the vast majority of these cases are minimal and mild TBIs (5). Narrowing it down to hospital admitted TBI, the incidence rate reduces to 83-262 per 100,000 people with increasing cases of severe and moderate TBIs (6-11). When it is further limited to hospital admitted patients with an acute neurocranial finding on computerized tomography (CT), the incidence rate drops even further to 26-42 per 100,000 people (7, 10-12).

As mentioned, minimal and mild TBI occurs evidently with far greater frequency than both moderate and severe TBI, and constitutes 80-90% of all TBIs (1, 5, 6). Between 8-15% of patients with minimal and mild TBI will have traumatic neurocranial findings on CT (13, 14), implying a potential worse outcome as compared to patients with a normal CT. Of these cases, less than 1%will require neurosurgical intervention following minimal and mild TBI, which is low compared to the total number of TBIs (14-20). Despite the low frequencies of cases being life-threatening, the burden of minimal and mild TBI is seemingly much greater than moderate or severe TBIs, given its much higher prevalence (21). A more detailed explanation and classification of minimal, mild, moderate and severe TBI will be elaborated in chapter 1.2.

1.2 Classification of TBI

There are currently wide variations in the classification of TBI. It is recognized to be one of the most challenging conditions to classify due to the heterogenous nature of both severity and mechanism of the trauma. Patients´ clinical presentation can also be difficult to assess as they have a considerable variation. Finding ways to classify these patients are essential for optimal management. (22). Recognizing a potential neurocranial injury requires good clinical assessment, understanding the injury mechanism and its severity and executing a mode to confirm the diagnosis, which is usually neuroimaging. TBI is commonly classified into the broad categories of minimal, mild, moderate and severe, which depends on injury severity, mechanism of the injury and pathoanatomy classification (23).

1.2.1 Classifying TBI by injury severity

TBI is frequently classified by severity on the basis of Glasgow Coma Scale (GCS)-score, which is a well-known and validated scale to assess the level of consciousness and can give an indication about the traumatic severity of brain injury (24). The scale is based on three clinical features: eye opening, verbal response and motor response (Table 1). The maximum score is 15, which indicates that the patient is unaffected, and the minimum score is 3 where the patient is in a coma. A TBI with a GCS-score of 15 is classified as minimal, 13 or above as mild, GCS-score of 9-12 as moderate and 8 or below as severe (14, 22).

Table 1 Glasgow Coma Scale (GCS)- score: *assessment of level of consciousness following TBI, with response outcome and possible scores, ranging from 3-15 (24).*

Response	Score
Eye opening	
Spontaneous	4
To speech	3
To pain	2
No response	1
Verbal response	
Oriented to time, place and person	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
No response	1
Motor response	
Obeys commands	6
Moves to localized pain	5
Flexion to withdraw from pain	4
Abnormal flexion	3
Abnormal extension	2
No response	1

Though the score is a well implemented tool, it presents with some drawbacks (23). The confounding effects of alcohol or other drug intoxication may affect the GCS-score of a patient and hence alter the injury assessment (14, 25). It is also argued that a single GCS-score is of limited prognostic value, especially in patients who present with mild TBI, as it is insufficient to determine the degree of parenchymal injury after trauma (24). Alone the GCS-score does not provide specific information about the pathophysiologic mechanisms of the underlying injury (23, 24).

In 1995 the Head Injury Severity Scale (HISS) was introduced as a diagnostic tool to estimate the severity of brain injury (Table 2) (26). The system is primarily based on the GCS-score, but also adds the aspects of duration of the altered consciousness during the post injury time period (27). Inclusion of the clinical variables such as loss of consciousness, retrograde amnesia

and focal neurological deficits assists in mapping the post injury time period. The score ranges from minimal, mild, moderate and severe TBI (26).

***Table 2 HISS-classification**: Classification of TBI by Head injury severity scale (HISS) (26)*

HISS-classification	Clinical criteria
Minimal	GCS-score[a] of 15 and no LOC[b]
Mild	GCS-score of 14 or 15 with <5 minutes of LOC or amnesia or impaired alertness or memory
Moderate	GCS-score of 9-13, or LOC ≥ 5 minutes or focal neurological deficit.
Severe	GCS-score of 3-8

[a] *GCS* Glasgow Coma Scale-score, ranging from 3-15
[b] *LOC* loss of consciousness

Globally, severe TBI only account for a small proportion of the injuries. A recent study estimated the incidence of severe TBI to be approximately 8%, followed by 11% accounting for moderate TBI. Minimal and mild TBI accounts for approximately 80-90 % of the cases of reported head injuries (1). As up to 90% of the cases are minimal and mild, some authors refer to them as a "silent epidemic". This is as a result of missed data, either due to cases being unreported by patients, or being unrecognized by health care professionals (1, 28). Symptoms of minimal and mild TBI and post-traumatic related problems are often not immediately visible, which may lead to underdiagnosis of these cases (6).

Compared to severe and moderate TBI, the high incidence of minimal and mild TBI will have larger impact as a group. It is argued to be one of the largest contributors for societal costs, where a total treatment cost across patients is nearly 3 times that of moderate and severe TBI (29).

1.2.2 Classifying TBI by pathoanatomy

Pathoanatomic classification of TBI targets the common neuropathological features of the injury, which are based on radiology findings. This includes the location of the neurocranial injury and the underlying causative process, which is most often an intracerebral bleed or fracture of the skull (23, 27). The most commonly occurring pathological features identified by this approach are represented in Table 3, arranged in an "outward-inward" manner (22).

***Table 3 Classification of TBI**: pathoanatomic classification, identified by radiologic examinations (22)*

Pathoanatomic finding
Skull fractures
Epidural hemorrhage (EDH)
Subdural hemorrhage (SDH)
Traumatic subarachnoid hemorrhage (t-SAH)
Cerebral contusion
Traumatic intraventricular hemorrhage
Diffuse axonal injuries (DAI)

Although any of these pathoanatomic findings can develop following TBI, some occur more commonly than others; intracerebral contusions, subdural hematomas (SDH) and traumatic subarachnoid hemorrhages (t-SAH) are more frequent, as compared to epidural hematomas (EDH) and intraventricular hemorrhage (30, 31). Figure 1 illustrates some of these findings.

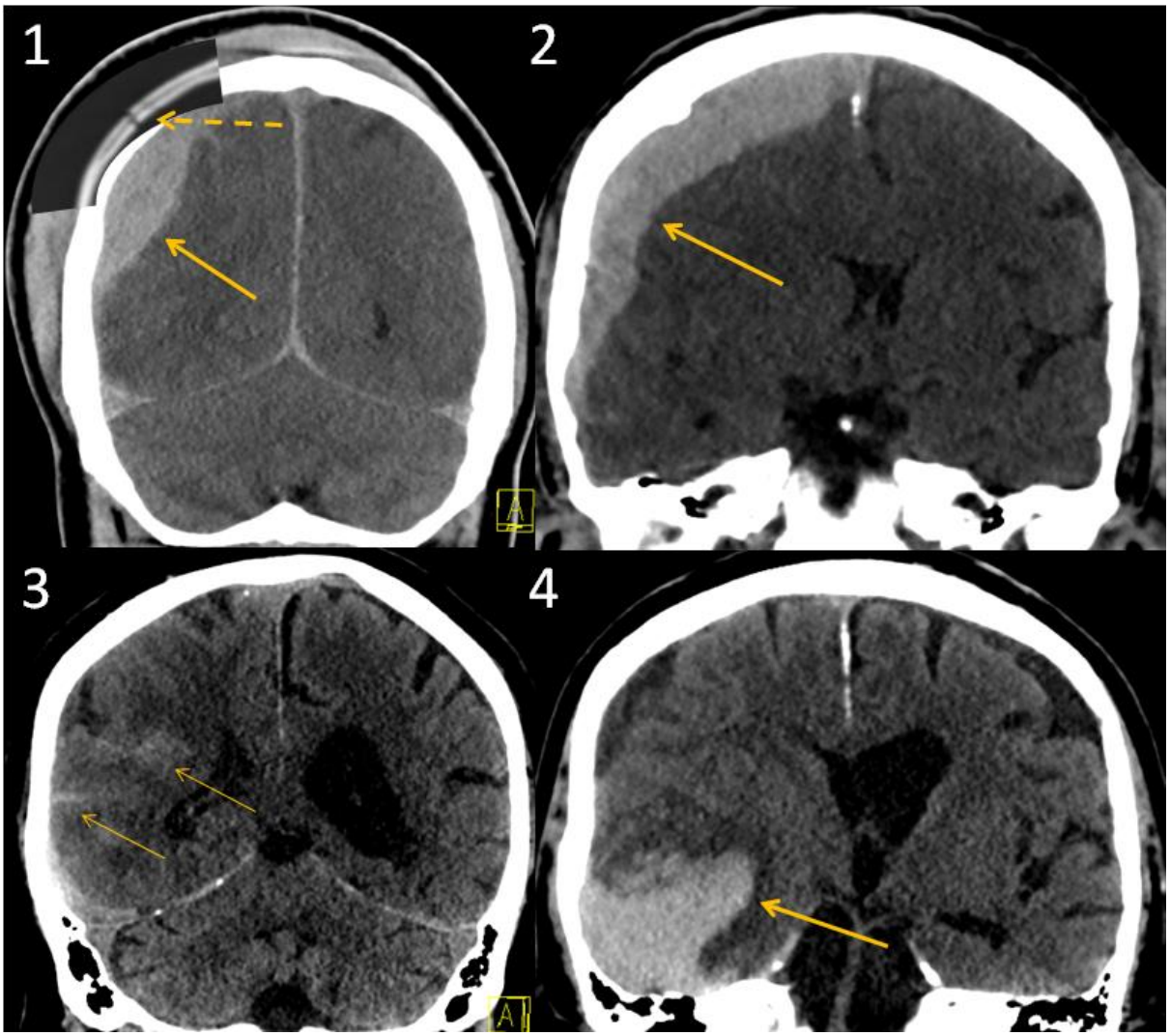

Figure 1. Head CT (coronal plane) following TBI*; 1: Skull fracture (arrow with spaced lines) and epidural hematoma (EDH) (arrow); 2: Subdural hematoma (SDH) (arrow); 3: Traumatic subarachnoid hemorrhage (t-SAH) (arrows); 4: Contusion hematoma (arrow). Courtesy of Neuroradiology department (OUS-Ullevål). With permission.*

As a singular classification system for all TBI, this approach has limited success in clinical practice, mainly due to the concurrence of numerous pathoanatomic lesions which can vary in severity and location (22). Moreover, pathoanatomic classification is mainly based on neuroimaging findings, and there are different classification schemes that exists based on these entities. The Rotterdam score is a recent CT-based classification system, where score predicts the outcome of patients with moderate and severe TBI based on different combinations of the CT-findings (32). Neuroimaging findings will be explained in more detail in section 1.5.

1.2.3 Classifying TBI by trauma and physical mechanism

Etiologically, TBIs can be categorized according to physical mechanism, which encompass injuries associated by blunt injuries (contact injury) or acceleration-deceleration forces (23). To some extent, these mechanisms can predict the traumatic intracranial pathology, where blunt injuries are more likely to cause focal injuries such as contusion and EDH, while acceleration-deceleration injuries are more associated with diffuse injuries, such as SDH and diffuse axonal injuries (DAI) (22, 23).

Additionally, a description of TBI relative to trauma mechanism has been demonstrated in several different epidemiological studies (5, 6, 10, 12). The frequency of finding neurocranial injuries on a head CT has been related to trauma mechanism, as this method provides valuable clinical information regarding the potential severity of TBI in relation to the trauma mechanism (33). Mechanisms that consists of a high amount of energy often results in increased potential for severe injury and are often described as high energy traumas. These include road traffic accidents (RTAs), falls from more than 3 meters. Comparatively, mechanisms that do not involve a high energy are described as low energy traumas most often include low falls (less than 1 meters) (34). Though the injury mechanism may not reveal the distinct intracranial pathology, it is able to provide valuable clinical information when evaluating the potential severity of the TBI (6, 35-39). Thus, classifying TBI by trauma and physical mechanism creates an impression of the physical energy and the potential TBI severity resulting from the impact, and can help guide the acute management of TBIs.

1.3 Patient related risk factors

The patient related risk factors are described in this section. Clinical risk factors related to TBI will be explained in section 1.4

1.3.1 Age

TBI has previously been reported to be more common in young adults, mainly due RTAs, but the epidemiologic trends have changed showing a shift towards the elderly population, due to falls (6, 37, 40, 41). Recent studies argued that TBI in older adults is an emerging major public health concern as they are known to be at higher risk of TBI (1, 42). This is mainly due to an increase in age in the general population which results in an expansion in both the general trauma population as well as TBI patients (43-45). The definition of elderly is variable, where the cutoffs in TBI studies range from 55 to 75 years. Several guidelines for TBI take this into consideration (15, 36, 46, 47) and will be discussed in section 1.5

TBI remains one of the leading causes of death in children and adolescents worldwide (1) . The reported incidence and causes of TBI varies greatly between countries and regions; in low income countries, RTAs account for most TBIs compared to high income countries, where falls greatly accounts for TBIs (1, 45). According to the US Centers for Disease Control and Prevention (CDC) children of 14 years or younger account for the second highest incidence of TBI for any age groups after older adults (>75 years) (38).

1.3.2 Anticoagulation therapy

Anticoagulation therapy and prescription antiplatelet drugs are prescribed mainly for cardiovascular diseases and are widely used by the elderly population (48). These medications are associated with worse initial TBI severity, where the patients can have a relatively minor trauma mechanism yet develop a significant intracranial injury (41). Some studies have related all classes of anticoagulation therapies with increased mortality and worse outcomes (48), while others have demonstrated a negative effect on outcomes with only anticoagulants, such as warfarin, and not antiplatelet drugs (49).

Although the outcome related to anticoagulated patients is unclear, it remains an important risk factor when evaluating this patient group in relation to TBI. Intracranial injuries following TBI may potentially have an adverse effect in patients on these medications, as it associated with worse initial TBI-severity after minor traumas (36, 50) and an increased risk of hemorrhage and hemorrhage progression (50-53). Thus, the use of anticoagulation therapy in combination with age is often identified as a risk factor when evaluating TBI patients (47)

1.3.3 Comorbidities

The most commonly reported co-occurring comorbidities related to TBI are nervous system disorders (stroke or dementia), circulatory and respiratory system disorders, and mental health disorders (54). Awareness of comorbidity in TBI patients is of great importance, because it is associated with high rates of hospitalization and longer hospital stay (36, 55). Studies have shown that additional illnesses or diseases in TBI patients may alter the management of patients in both the acute and rehabilitation phase, and consequently may affect the healthcare services and outcomes (54, 56, 57).

Due to the increased incidence of TBI in the elderly population, who commonly have multiple comorbidities, are often at risk for sustaining TBI (36). Consequently, this is becoming an additional consideration when managing these patients (58).

1.4 Clinical Guidelines for management of TBI

Identifying which patients with a TBI that may have an acute and potentially life-threatening neurocranial injury is challenging for both inexperienced and experienced physicians, as the majority of these patients with TBI are classified as minimal and mild TBI (59). Early complications following a minimal and mild TBI are infrequent; as mentioned before, research show that between 8-15% of patients with mild TBI have an acute neurocranial injury (13, 14). These acute injuries are however rarely life-threatening, and less than 1% of these patients will require neurosurgical intervention (14-20, 60), although these acute cases need rapid and reliable diagnosis. Given the relatively low incidence of neurocranial injuries after minimal and mild TBI, selecting and identifying these patients that are at risk of developing life-threatening injuries is the primary goal, (61) while still maintaining high-quality and cost-effective care (62). Scanning all patients in order to detect a potential neurocranial injury seems inefficient and would lead to a large amount of unnecessary CT scans and possible radiation induced cancer (63-65). Nonetheless, prior studies report an increased number of patients presenting to the ED with minimal and mild TBI (66, 67), whilst the overall incidence of TBI mortality has remained stable (61, 68).

Both international and national clinical guidelines have been published in order to assist the physicians in the management of TBI patients, allowing the physicians to be more selective in the use of CT, without compromising the patientcare, and aid physicians to make proper clinical decisions (62, 69)

1.4.1 International clinical guidelines

The most studied and frequently used guidelines are the New Orleans Criteria (NOC), Canadian CT head rule (CCHR), the CT in Head Injury Patients (CHIP) prediction rule and the National Institute for Health and Care Excellence (NICE) guideline (15, 16, 20, 70).

These clinical guidelines include different sets of inclusion and exclusion criteria for diagnosing and classifying TBI. The guidelines offer a set of decision algorithms to identify and distinguish the patients at risk for developing neurocranial injuries and consequently neurosurgical intervention, and the patients who can safely be discharged (71).

Most of the guidelines consider the presence of particular clinical signs and symptoms, specified as risk factors, as increasing the risk of a potential neurocranial injury. These risk-factors include loss of consciousness, reduced GCS-score, posttraumatic amnesia, focal neurological deficit, post-traumatic seizure, emesis or anticoagulation therapy. However, the

difference between the guidelines in terms of the definitions and combination for these risk factors, results in a variation of head CT indication (72, 73). Although different for the individual guidelines, decision-making algorithm in these also differ with respect to which patients to scan and not; strict criteria often imply that only high-risk patients should be scanned, whilst lenient criteria allows both medium-risk and high-risk patients to undergo a head CT (74).

Although the guidelines have been externally validated and are commonly used internationally, the reported sensitivity and specificity differs among the different guidelines, where the number of head CTs required to detect the relevant injuries varies (62, 74). Guidelines with higher sensitivity comes with a cost of high numbers of head CTs, whilst guidelines that leads to reduced number of CTs has a lower sensitivity as a consequence (14, 61)

1.4.2 Scandinavian guidelines

In 2000, the Scandinavian Neurotrauma Committee (SNC) published evidence-based guidelines for the management of minimal, mild and moderate TBI in adults, where the TBI are classified according to the HISS-scale. The establishment of the guidelines was done in order to strengthen the care and management of TBI patients in the Nordic countries and in accordance with the Nordic healthcare systems (75).

In 2013, the SNC published an updated version of the guidelines with regard to new evidence, and subsequently introduced analysis of a brain biomarker (S100B) (47). This analysis is considered as an alternative to head CTs in patients with low risk of developing neurocranial injury. The goal of using this analysis is to accurately predict the absence of neurocranial injury, indicated by a value below cut-off-value (0.10 µg/l), where it allows for a safe reduction of head CTs in patients who otherwise are at low risk of developing injuries.

The SNC guidelines offer evidence-based decision rules on how to manage the patients at risk for developing neurocranial injuries following a TBI. The decision rules provide a set of clinical risk factors to select patients eligible for a head CT, and/or hospital admission. Additionally, the guidelines also provide instructions for appropriate discharge of patients without any risk for developing neurocranial injuries. The risk factors defined by the SNC guidelines are listed in Table 4 (47).

Table 4 Risk factors and clinical definitions: *SNC guidelines clinical definitions of risk factors for evaluating minimal, mild and moderate TBI (47)*

Risk factor	**Clinical definition**
Age	≥65
GCS-score	<15
Loss of consciousness	Confirmed or suspected
Anticoagulation therapy	Includes any coagulation disorder, anticoagulant therapy or antiplatelet medication
Focal neurological deficit	Motorial impairment such as function loss
Post-traumatic seizures	Confirmed or suspected with clinical signs -for example: involuntary urination or tongue biting
Shunt-treated hydrocephalus	Based on clinical anamnesis
Clinical signs of depressed or basal skull fracture	Hemotympanum, rhinorrhea, otorrhea, periorbital or mastoid ecchymosis
Emesis or gagging	More than two repeated episodes

Note: *GCS*: Glasgow Coma Scale-score; *Hemotympanum*: presence of blood in the middle ear; *rhinorrhea*: bloody fluid in nasal cavity; *Otorrhea*: bloody fluid in ear; *periorbital ecchymosis*: presence of blood in tissue surrounding eyes; *mastoid-ecchymosis*: presence of blood in tissue behind ears

The guidelines include evaluation of minimal, mild and moderate TBI, where the mild TBI group have further been subdivided into categories including low-risk, high-risk and moderate-risk. The goal of subdividing the mild TBI group is to distinguish the patients who require a head CT and/or hospitalization/observation, and those who can undergo a S100B analysis as an alternative. Thus, the guidelines (47) include five categories with different clinical risk factors and recommendations:

i) *Minimal TBI*: includes patients with a GCS-score of 15 and no other risk factors present. These patients can safely be discharged without a head CT or S100B analysis.

ii) *Mild TBI low-risk*: includes patients with a GCS-score of 14 and no other risk factors, or patients with a GCS-score of 15 and confirmed or suspected loss of consciousness, or at least two episodes of repeated emesis or gagging. If there is less than 6 hours since the injury, these patients may be subjected to S100B analysis. If the analysis is negative (below 0.10 µg/l), the patients may be safely discharged without a head CT. When the S100B analysis is positive (above 0.10 µg/l), or it has been more than 6 hours after the injury, or S100B analysis is not available, a head CT is recommended. With a normal head CT, the patient can be safely discharged.

iii) *Mild TBI medium-risk:* includes patients with a GCS-score of 14-15, are above 65 years of age and are using antiplatelet medication (such as aspirin or clopidogrel), where a head CT is recommended. With a normal head CT, the patients may be discharged.

iv) *Mild TBI high-risk*: includes patients with a GCS-score of 14-15 and has at least one of the following risk factors present: shunt-treated hydrocephalus, focal neurological deficit, post-traumatic seizures, clinical signs of depressed or basal skull fracture, uses any anticoagulation therapy (such as coumadin or warfarin) or has a coagulation disorder. These patients are recommended a head CT and observation for at least 24 hours, regardless of the CT results.

v) *Moderate TBI:* includes patients with GCS-score of 9-13 and no risk factors. These patients are recommended a head CT and hospitalized irrespective of the CT results.

Though the guidelines have been externally validated, some studies reported an over triage of patients and low guidelines compliance, consequently leading to an increase in head CTs (76, 77). A recent study proposed a possible explanation for this to be the frequent alcohol consumption in patients presenting with TBI (78). Despite this, the SNC guidelines do not consider alcohol and drug intoxication as risk factors.

1.5 Neuroimaging in traumatic brain injury

Neuroimaging plays a central role in the management of TBI patients. It is extremely sensitive at detecting neurocranial injuries and its secondary damage to brain parenchyma and mass effect. Patients who need surgical intervention are also identified by imaging. Imaging modalities mainly encompass CT and Magnetic resonance imaging (MRI). (79)(69).

1.5.1 Computed Tomography

Since the introduction of CT in the 1970s, it has revolutionized the management of acute and chronic diseases. The most common imaging modality in the management of TBI patients is non-contrast head CT, because it is readily available, fast and noninvasive (80). CT is also highly sensitive and specific in detecting neurocranial injuries, making it an excellent primary diagnostic tool (21).

The initial role of head CT in an acute setting is to identify the potential neurocranial injuries following a TBI. CT is therefore particularly beneficial in the context of moderate and severe TBI, where a higher proportion of these patients may have a significant injury (80). In minimal and mild TBI, the prevalence of both neurocranial injuries and intervention is far less. Though the goal is still the same; to identify the life-threatening injuries. The leading challenge is to distinguish the patients who requires a head CT and those who do not (80, 81). As discussed earlier, clinical decision algorithms assist in this selection (82). Though there are multiple guidelines available, concluding with a head CT is not uncommon in this patient group and is persistently increasing (63, 83).

Despite its clear utility, CT also has its limitations; effects that may degrade image quality (such as beam-hardening effects) can lead to misinterpretation by either overdiagnosing or misdiagnosing hemorrhages. Also, head CTs preformed within 3 hours of trauma may underestimate injury, and in some cases miss small bleeds where the blood has not yet coagulated and will not attenuate the x-ray beams in order to be detected by the scanner (31)

Additionally, there is a growing concern for unnecessary radiation exposure and radiation induced cancer with regards to CT use (65). In relation to TBI, this may pose as a major public health concern, where especially children and patients receiving a high amount of head CTs are at greater risk for developing radiation induced cancer (84, 85). Though some patients may benefit from a head CT, it would deem unnecessary to scan all mild TBI, particularly due to its high prevalence. Yet, the use of CT is growing and potentially exposing patients to otherwise avoidable radiation (86, 87).

Both international and national institutions have dispersed awareness regarding the overuse of CT. In 2012, the Norwegian Radiation Protection co-operation expressed their concern over the rapidly increasing amount of CT examinations in Norway, where Norway had the highest amount of CT examinations among the Nordic countries (88). The report encourages to avoid unnecessary CT scans where there is little or no benefit to the patient. Similarly, as part of the Choosing Wisely Initiative (89), the American College of Emergency Physicians (ACEP) developed sets of clinically relevant questions in terms of head CT, where it is also advocated towards restricted use of CT in the low-risk TBI patients (90)

1.5.2 Magnetic resonance imaging

MRI is often the modality of choice for mapping the extent of the injury in the subacute phase of patients with proven or suspected neurocranial injury; MRI is rarely used as a primary imaging modality in TBI patients (80, 91). Though MRI is limited in primary assessment of TBI, it is especially useful in cases where the head CT is negative, despite presence of clinical symptoms (21, 92). Cerebral MRI is far more sensitive than CT for detecting non-hemorrhagic contusions, DAI and ischemic injuries (92, 93).

Despite valuable information provided with MRI scanning, its limited in acute clinical practice; the advantages and convenience of CT have restricted the use of MRI in acute management of TBI (81); this partially due to limited availability in many clinical settings, costs, and longer imaging times combined with sensitivity to patient motion (14, 92). The role of MRI in acute evaluation of TBI still remains unclear (81, 93).

1.6 Management of TBI patients

1.6.1 Conservative

The vast majority of TBI patients are conservatively managed, although it is more common in the mild and moderate cases (94). Granted that an intracerebral hemorrhage is found on the primary head CT, a follow-up head CT is often preformed 6 hours after the initial one. This acts as a control measure for a potential progression of the hemorrhage that needs further neurosurgical intervention (95). The role of repeat head CTs is unclear in the literature, and variation exists among clinical settings (96, 97). Particularly with regards to neurologically stable patients and smaller intracerebral hemorrhages, some studies question the need of repeat head CTs (98, 99). In contrast, multiple authors advocates for the predictive value of repeat head CTs (96, 100, 101).

Other aspects of conservative management include observation of TBI patients, commonly for 12-24 hours. Assessed by the extent of the intracerebral hemorrhage, this is usually done either as an admitted patient, or at-home observation by a responsible adult (99, 102). The SNC guidelines recommends admission of patients for observation following a mild (medium- and high-risk) or moderate TBI (47)

1.6.2 Neurosurgical intervention

Following a TBI, different kinds of intracerebral hemorrhages may develop, and those requiring neurosurgical intervention are mostly identified soon after presentation (101). Neurocranial injuries requiring intervention occurs more frequently in severe TBI, and less mild and moderate cases (95). Depending on the severity and the amount of mass effect created, these injuries can potentially be life-threatening (103).

Generally, the need for intervention is associated with clinical deterioration and expansion of the intracerebral hemorrhage. Intracranial pressure (ICP) monitor is a widely used to monitor the amount of damage to the brain (104). This is done by a probe inserted into the brain via a burr hole (Figure 2). ICP is also used for surgical decision making (105).

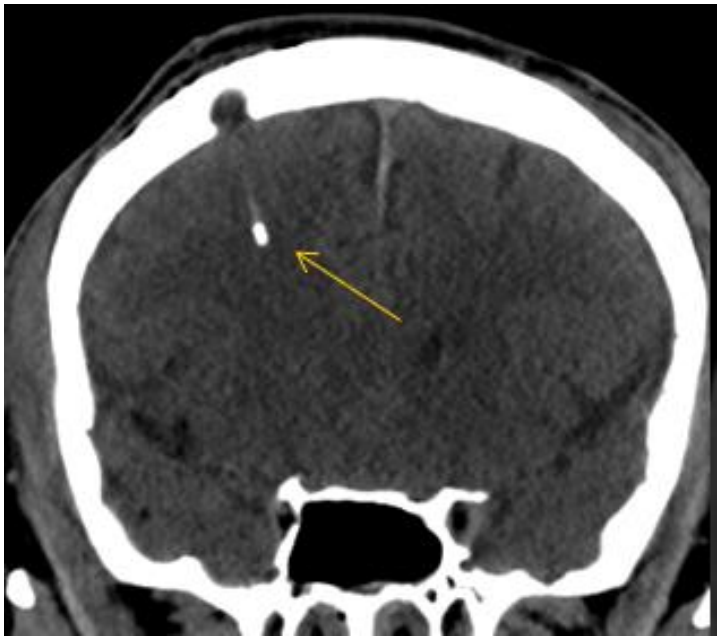

Figure 2 Coronal plane of head CT*; illustration of ICP monitor (arrow) inserted via a burr hole, following a TBI. Courtesy of Neuroradiology department (OUS-Ullevål). With permission*

Initial neurosurgical treatment of TBI mainly involves burr hole, craniotomy and decompressive craniectomy (105). Burr hole surgery is a small hole drilled into the skull to insert ICP monitors, extra ventricular drains and to evacuate liquified hematomas. For craniotomies, a bone flap is removed to gain access to acute hemorrhages for evacuation, following reinsertion of the bone flap. To decompress the brain, often due to edematous parenchyma, the bone-flap is removed at surgery, and placed back at a later stage (decompressive craniectomy) (105, 106). Figure 3 illustrates CT images of some of the common neurosurgical procedures.

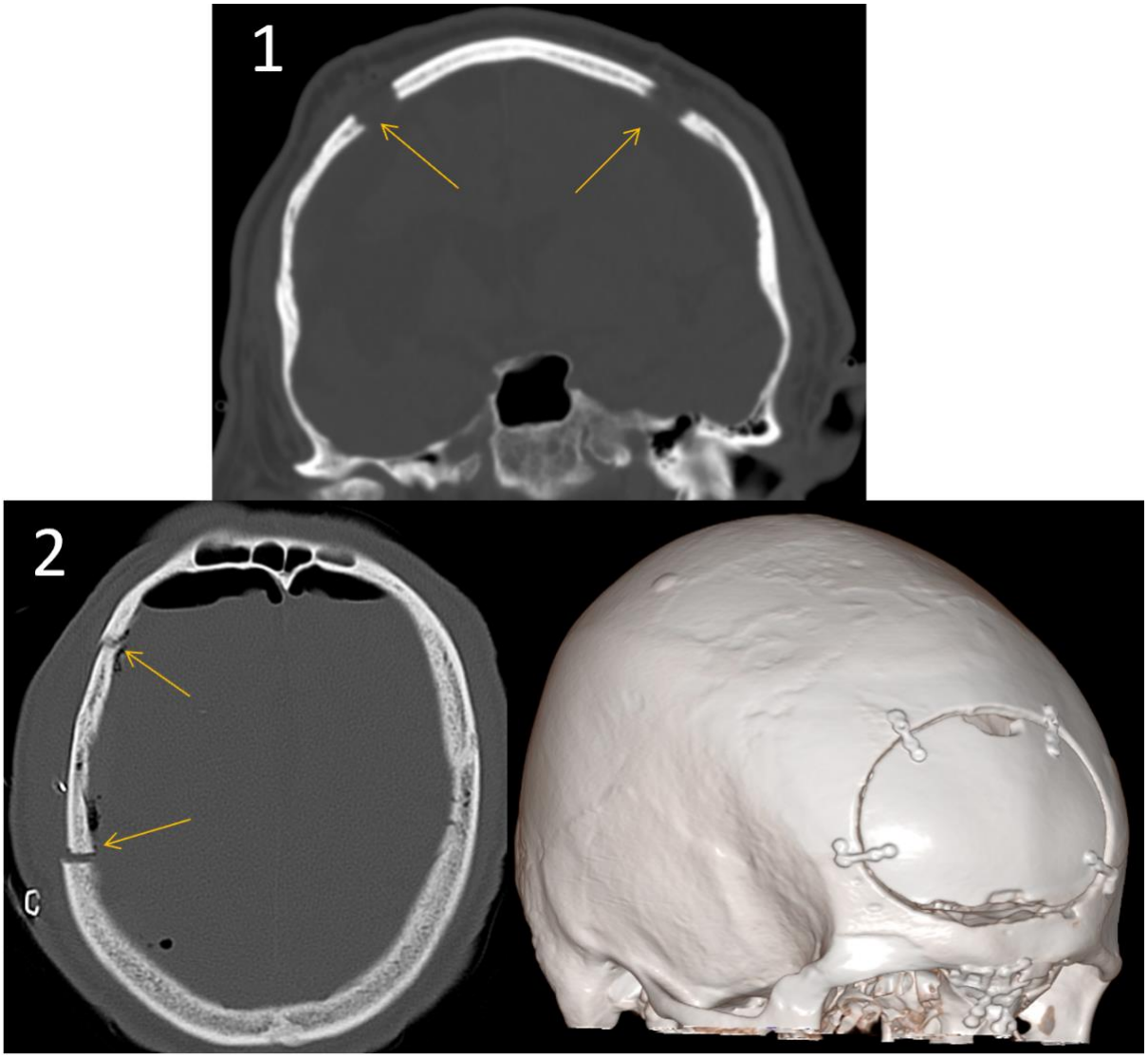

Figure 3 CT images of neurosurgical intervention following TBI*; 1: Bilateral burr hole (arrows) to evacuate hemorrhage or insertion of ICP monitors, 2: Craniotomy involving removal of bone flap for evacuation of hemorrhage with reinserted bone flap (arrows). Courtesy of Neuroradiology department (OUS-Ullevål), with permission.*

1.6.3 Follow-up

After the initial acute phase, the majority of the patients with minimal and mild TBI fully recover within weeks following the injury, and receive little or no follow-up (107, 108). Some authors have however reported that an outpatient follow-up of patients with persistent symptoms following TBI may be indicated (109), although this practice varies among clinical settings (108).

Patients with nonsurgical neurocranial injuries are recommended hospitalization for observation (47) and then usually followed up in the neurosurgical outpatient clinic afterwards (108, 110). With any kind of intracranial hemorrhage following TBI, patients will lose their driver's license for at least 6 months by law in Norway (111).

Patients with moderate and severe TBI commonly require hospitalization or admission for observation and are followed up by neurorehabilitation facilities as they often suffer with neurological deficits of different degrees (112, 113).

2.0 Aim

Minimal, mild and moderate TBI poses difficulty in identifying the patients at risk of developing life-threatening traumatic neurocranial injuries. Guidelines have therefore been implemented to allow a more selective use of CT, and subsequently improving clinical practice and patient outcome (62, 69). As it appears in the literature, the high incidence of minimal and mild TBI often results in overtriage of patients and unnecessary head CTs preformed (114, 115).

Recent European studies (6, 116, 117) have described a shift in the age and injury mechanism in the TBI population; we hypothesize that this trend is also reflected in the TBI population at Oslo Emergency Department (OED). It is also hypothesized that there is excessive use of unnecessary head CTs at OED. Hence the aim of this study is two-fold; firstly, we will review the TBI population at OED as a cohort. To do this we will assess the frequency of TBI patients, describe patient characteristics and demographics, and the number of patients with neurocranial injury. Secondly, we will assess guideline compliance at the OED by analyzing the clinical information from the CT referral forms.

3.0 Material and Methods

3.1 Clinical setting

Oslo Emergency Department (OED) is an emergency department and is part of the level one trauma center Oslo University Hospitals (OUS) covering the South-Eastern Norway Regional Health Authority. OED is at a separate location from the other University hospitals and serve as an emergency department for more than 690,000 inhabitants in the Oslo-region (118). Patients commonly present to the OED either through paramedical services or by self-referral.

Depending on the extent of the trauma, patients with minimal, mild and moderate TBIs are primarily evaluated at the OED, whilst severe TBIs are generally treated at OUS-Ullevål, as this is the only hospital in the region who offers neurosurgical service. When the patients at OED requires further management, they are transferred to OUS-Ullevål. The SNC guidelines are part of clinical practice at the OED when evaluating TBI patients. Also, it is standard practice at the OED to only preform head CTs on adult patients (above 16 years old). Younger patients with TBI are evaluated at local hospitals and they assess the age appropriate management.

3.2 Study population and inclusion process

In this retrospective study, we included all consecutive patients that were assessed and received a head CT at the OED for minimal, mild or moderate TBI, between January-June 2016. The six-month study period was chosen in order to include the seasonal differences of the diverse types of trauma in the population and their respective various trauma mechanisms.

All patients included were 16 years or older and had a primary head CT carried out at the study site following a TBI. Exclusion criteria included; no head CT preformed or if a repeat head CT was preformed after a positive primary CT. After exclusion of these patients, 2000 primary head CTs were included in the study. The study selection process is illustrated in Figure 4.

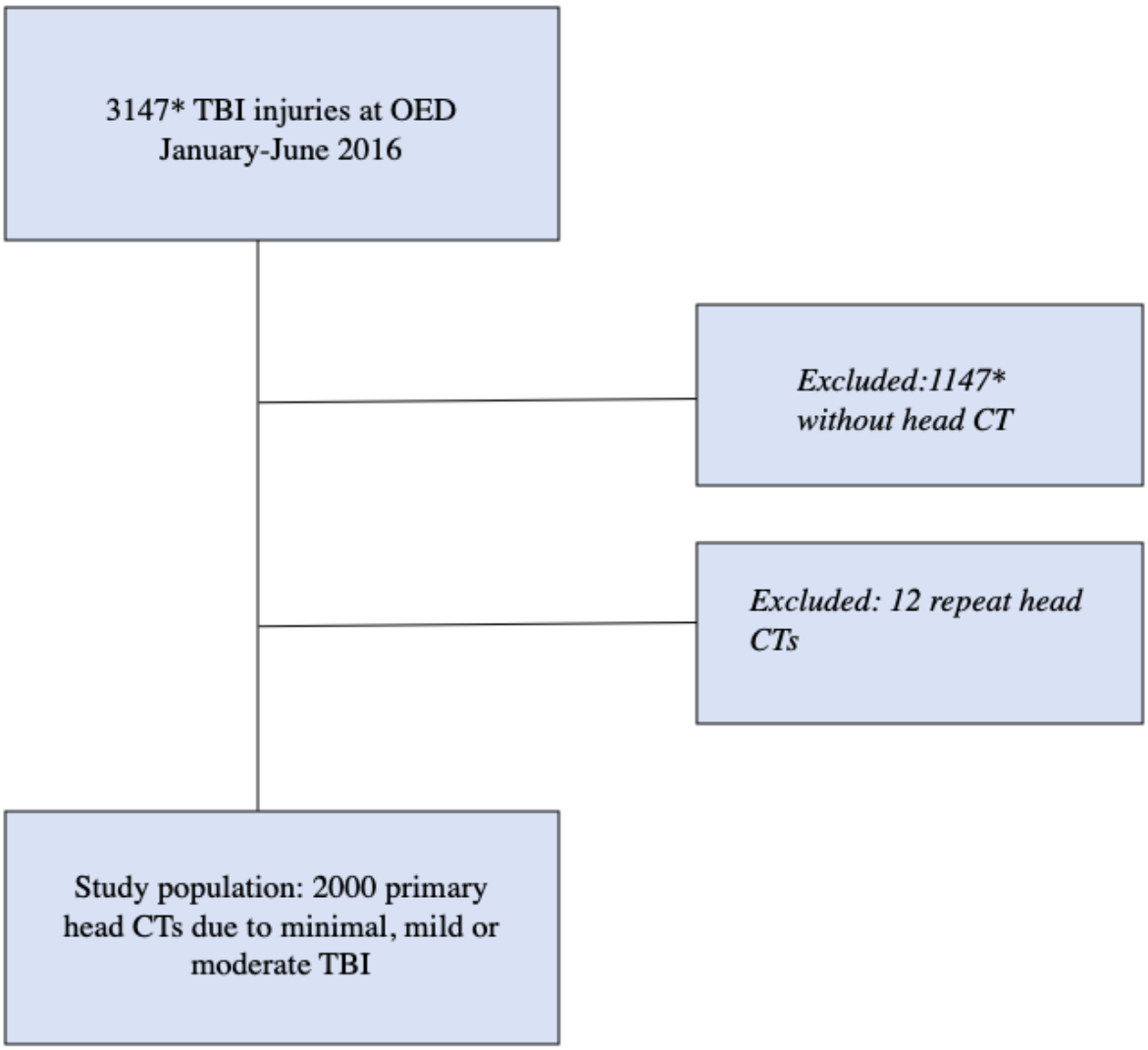

Figure 4 Selection process of the study. *Illustration of the inclusion and exclusion process leading to 2000 patients with a primary head CT preformed at the OED following a minimal, mild or moderate TBI. Note: * indicates numbers of TBI patients in 2016, provided by the OED management, identified with International Classification of diseases codes (ICD-10): n=6295 TBI injuries for 2016, n=3147 estimated TBI patients in study period.*

3.3 Data collection

In order to review the TBI population at OED and assess the SNC guideline compliance, the data was collected from both the CT referral form and the radiology report. The data was reviewed retrospectively through the electronic radiologic information system (RIS), where both the CT referral form and radiology report is available. No additional clinical information from the patient's Electronic Health Record (EHR) was gathered, to evaluate the extent of clinical information available in the referral form.

3.4 Data collection from the CT referral form

3.4.1 Demographics, clinical risk factors and additional clinical variables

The electronic CT referral form is submitted by the treating OED physicians. Patient demographics (age and gender), injury mechanism, and the clinical risk factors defined by the SNC guidelines (47) (GCS-score, anticoagulation therapy, loss of consciousness, focal neurological deficits, posttraumatic seizure, shunt-treated hydrocephalus, emesis, gagging, clinical sign of skull fracture) were retrieved here (Table 5).

Additional clinical variables from other clinical guidelines (15, 16, 70) were also recorded in the data collection and included headache and amnesia. This was done in order to encompass the heterogeneity of the TBI patients and the aim was to give a comprehensive overview of different clinical variables. Symptoms that were otherwise not described in any of the aforementioned guidelines were also included in this variable. This involved falls due to generalized tonic-clonic seizures, syncope or difficulty obtaining anamnesis due to the patient's condition (Table 5). Clinical risk factors and additional clinical variables were mutually exclusive; hence no patient was recorded in both categories.

Although not primarily defined as a risk factor in the SNC guidelines, evidence of drug and alcohol intoxication was also recorded. This was due to the high prevalence of intoxication in TBI patients (47) (Table5).

Table 5 Collected data on TBI population*: history and physical examination, SNC defined risk factors (47) and additional clinical variables.*

History and physical examination
Age
Gender
Injury mechanism
Clinical risk factors defined by SNC guidelines
GCS-score
Anticoagulation therapy
Loss of consciousness
Focal neurological deficits
Posttraumatic seizure
Shunt-treated hydrocephalus
Emesis
Gagging
Clinical signs of depressed or basal skull fracture
Additional clinical variables
Intoxicationω
Amnesiaω
Headacheω
Other symptoms*

GCS: Glasgow Coma Scale-score
ωClinical variables based on international clinical guidelines (15, 16, 70)
*Other symptoms included falls due to generalized tonic-clonic seizures, syncope, somnolent, altered behavior or difficulty in obtaining anamnesis due to patients' condition.

3.4.2 Clinical definitions of risk factors and clinical variables

The SNC guidelines states that both confirmed and suspected loss of consciousness should be regarded as a risk factor, as it is often difficult to confirm any loss of consciousness in a clinical setting (47). Hence, confirmed loss of consciousness was included if it was reported by a witness or the patient, and cases where loss of consciousness was unknown was equated with suspected loss of consciousness.

Anticoagulant treatment included all types of antithrombotic therapies and platelet aggregation inhibitors, as it is seldom distinguished on the CT referral forms. Any type of coagulation disorder was also included in this variable.

Further, focal neurological deficits were defined as any sign of disruption to the central nervous system i.e.; double vision, asymmetrical motor reactions and unilateral paralysis. Post-traumatic seizures included both witnessed or suspected seizure following the TBI and did not include any patients with pre-injury epilepsy. Further, presence of shunt-treated hydrocephalus was derived from patient history.

Although the SNC considers at least two episodes of emesis as a risk factor, we included any episode of emesis in the data collection. This was done in order to capture the difference in clinical symptoms within the TBI population, as we hypothesized that this may vary among the TBI patients. Also, there was a discrepancy between the English and the Norwegian version of the SNC guidelines regarding this risk factor; the English version of the SNC guidelines defines at least 2 episodes of repeated emesis as a risk factor, whilst the Norwegian version includes a combination of gagging and emesis as a risk factor. Thus, we also decided to include multiple gagging.

The presence of drug or alcohol intoxication was evaluated clinically by the physician, based on the history obtained from the patient or witnesses, or based on any clinical findings that suggested intoxication such as slurred speech, alcohol odor, needle marks, etc.

Headache was defined as any new head pain, including both diffuse and localized pain. Posttraumatic amnesia was described as an inability to recall either pre or post-traumatic events. Also, a history of both witnessed or recalled syncope were included.

The Injury mechanism were categorized into falls, violent assaults, RTAs, incidence of unknown event or no injury mechanism reported.

The possible outcomes for the clinical variables and symptoms where classified as:

- Present
- Not present
- Unknown.

As mentioned earlier, the outcome of *unknown* for loss of consciousness was regarded as suspected loss of consciousness, in order to avoid under-triage of patients. However, this was not the case for antithrombotic use and intoxications; when the outcome was reported *unknown* it implied as missing clinical information.

Where the GCS-score was not included in the CT referral form, it was reported as an unknown variable. It was contemplated to assume that these patients had a GCS-score of 15, however this was not done as it would result in bias information. Consequently, we were able to get an overview of the amount of clinical information that was not included in the CT referral form.

3.4.3 Classification of the TBI population and compliance with the SNC guidelines

In order to assess the guideline compliance, the patients were first classified according to their relevant TBI categories. As described in section 1.4.2, the presence of specific risk factors corresponds to a predefined SNC guideline category, hence patients were categorized accordingly (Figure 5)

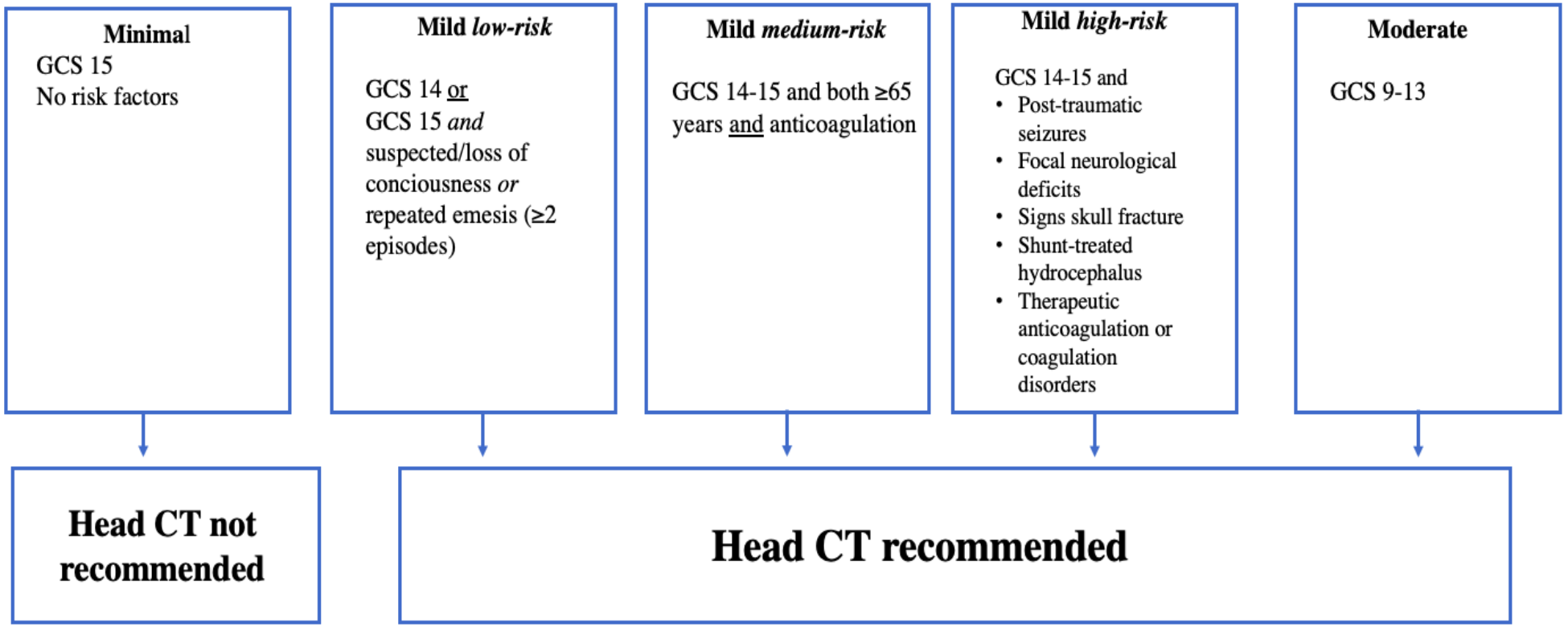

Figure 5 SNC guideline classification: *Illustration of the classification of TBI according to the SNC guidelines (47) and the categories recommended a head CT and those who are not*

Following the classification of the patients, guideline compliance was assessed as to whether or not the use of CT was in accordance with the guidelines. Compliance was considered in the categories where the guideline recommends a head CT; mild and moderate. Non-compliance was presumed in the minimal category as the guidelines do not recommend a head CT.

It should however be noted that this study only assessed compliance with CT recommendation, and did not include guideline compliance regarding patient management in terms of hospitalization or observation.

3.5 Data collection from the radiology report

The data collected by the radiology report included all findings detected on the head CT. All reports were produced by either resident radiologist on call or a neuroradiologist. All reports are signed by a neuroradiologist. This process is known as double-reading, which is a routine in Norwegian hospitals, and is done as a quality control procedure (119).

The primary outcome measures for the CT scan was a positive CT or a negative CT. A positive head CT was defined as the presence of any neurocranial finding, including any intracranial bleeds, skull or skull base fracture, caused by trauma. The intracranial bleeds were categorized into; EDH, SDH (including both acute and subacute), t-SAH, or intracerebral contusion. The skull fractures included depressed or linear skull fracture (Table 6). No patients had intraventricular bleeds or DAI; hence this was not included.

***Table 6 Neurocranial findings**: Neurocranial findings collected from the radiology report, defined as a positive CT*

Positive head CT
Epidural hematoma (EDH)
Acute and subacute subdural hematoma (SDH)
Traumatic Subarachnoid hemorrhage (t-SAH)
Contusion
Fracture of the skull (depressed or linear)

The patients requiring non-surgical intervention in terms of control CT due to the neurocranial findings were also collected, and defined as control CT. A positive head CT that subsequently lead to neurosurgical intervention was considered a secondary outcome. A neurosurgical intervention was defined as any of the following neurosurgical procedure: craniotomy, craniectomy, ICP monitoring or extra ventricular drainage, performed within 7 days after the injury.

A negative CT was defined as no relevant traumatic findings, and the CT scan was considered normal.

Missed traumatic neurocranial findings by radiology resident was classified as missed bleeds. It is important to assess the clinical consequence of resident doctors reporting on these scans.

3.5.1 Incidental pathological findings

Incidental pathological findings are always present when scanning patients and their potential clinical implications needs to be addressed. Hence incidental findings, from the radiology report, were described as any non-traumatic pathological process, that otherwise did not lead to a positive head CT, such as tumors and cerebral stroke.

3.5.2 Number of head CTs in past five years

Any ED are subjected to “regulars”. These patients also tend to present with similar presentations, such as falls due to intoxication. Subsequently they also receive multiple head CTs. To catch this potential excess radiation exposure to a certain TBI population group, we identified and noted patients who received more than one head CT during the past five years.

3.6 Head CT protocol

All patients included in the study were subjected to a head CT scan after presenting to the OED following a TBI, and all head CTs were requested by ED physician. The considerable difference between OED and other institutions is that the reporting radiologist is at another location and is not asked to accept or give a protocol for the CT, hence a head CT for TBI patients at OED is an order to the radiographer rather than a referral to a radiologist.

CT scan are available 24/7 at the OED. To decrease waiting time for patients the head CTs are reported on within 30 minutes by a radiologist at OUS-Ullevål.

All CT scans were performed on the same CT machine, Philips Brilliance 16 (Amsterdam, Netherlands) which was installed at the OED in 2007. The same scanning protocol was utilized for all patients, and in accordance with manufacturer specifications (Table 7). No patient received intravenous contrast media, as indicated by the protocol for a traumatic head CT.

Table 7 Head CT scanning protocol: Scanning protocol for head CT *with exposure parameters*

Parameter	Scan type	kVp	mAs	Pitch	Rotation	Collimation	Reconstructed thickness
Setting	Axial	120	520	1.0	1.5 s	16 x 1.5 mm	3/3 mm

kVp kilo Volt peak; *mAs* milliampere-seconds

If any substantial traumatic injury was found or any relevant changes were made to the radiology report, the radiologist would inform the referring physician by telephone and it was also recorded in the report.

3.7 Statistical analysis

The study population was described in terms of demographic characteristics, mechanism of injury, positive CT, neurosurgical interventions and guideline compliance; descriptive statistics were used to summarize this data. Test for normality was done using the Shaprio-Wilk test and Q-Q-plots for visual inspection. Continuous variables were expressed as median with range or inter quartile range (IQR) where applicable (data was not normally distributed). Categorical data were expressed in terms of frequencies and percentages.

The Mann-Whitney U test was preformed to determine the age distribution by positive or negative head CT. The number of positive head CTs was expressed as frequencies, along with their relevant SNC guideline category.

The Chi-square test for independence (X_2) was used in a contingency table to test for significant relationship between categorical data. It was also used to analyze the relationship between a positive CT and the risk factors; when the test showed a significant relationship, a Post-Hoc test in the form of adjusted standardized residual analysis was conducted (120). All *p*-values were adjusted using the Bonferroni correction, in order to minimize Type I error.

P-values less than 0.05 were considered significant. The data was collected in Microsoft Excel and analyzed using IBM Statistical Package for Social Sciences (SPSS) version 26.0.0. Graphs and figures were illustrated using GraphPad Prism version 8.4.1 (GraphPad Software, La Jolla California, USA).

3.8 Ethical considerations

Anonymized data was retrieved; data involving patient relevant information only included birth year. The study was approved by the Oslo University Hospitals Data Protection Officer (DPO) (Appendix 1). The study qualifies as a quality improvement project, hence application to the regional ethical committee (REC) was waived (121).

4.0 Results

Between January and June 2016, 2000 consecutive patients with minimal, mild and moderate TBI were evaluated at our emergency department. The data retrieved from the CT referral form and radiology report are presented separately.

4.1 Data from CT referral form; patient characteristics and demographics

General patient characteristics and demographics was collected from the CT referral form and included age, gender, trauma mechanism. Substance consumption in the form of intoxication is also presented in this section.

4.1.1 Age and gender

The median age of the total study population was 54 years (range 16-104 years), where the largest patient group was the adult group (age 31-64 years). There was a slight male predominance (54.8%) in the overall study population, where the male-to-female ratio was 1.2:1.0. General patient characteristics is described in Table 8.

***Table 8 Results from CT referral form**: General patient characteristics in the TBI study population (n=2000)*

General patient characteristics	**Total number** N=2000
Gender	
Males	1097 (54.8%)
Females	903 (45.2%)
Age	
Median (range)	54 (16-104)
Young adults (16-30)	428 (21.4%)
Adults (31-64)	820 (41.0%)
Elderly (≥65)	752 (37.6%)

A further analysis of age distribution among males and females revealed that the male dominance decreased with increasing age; the proportion of females in the patients above 65 years of age was 58.2%. This was also evident when comparing the median age between the two genders, where the median age differed significantly for males and females; 48 years and 64 years respectively (Mann-Whitney U test, $p < 0.05$). The age distribution among the genders is illustrated in Figure 6.

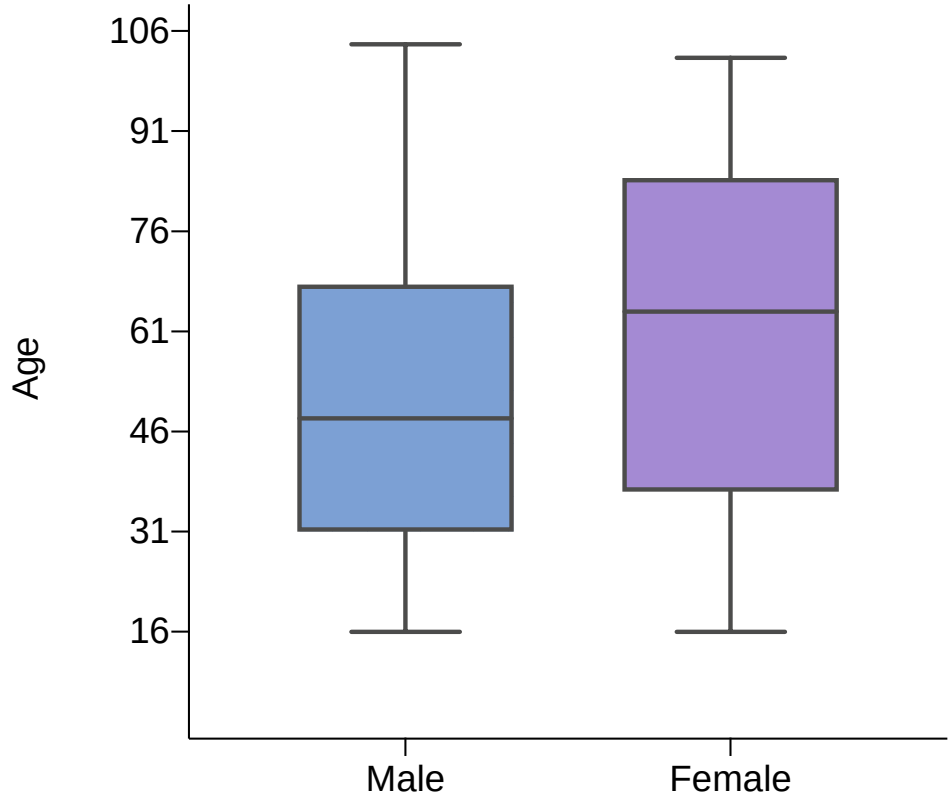

Figure 6 Box-plot illustration of age distributions among gender*: Age distribution between gender of the TBI population (n=2000), presented with median age, interquartile range (IQR) and range (minimum-maximum) of age : males (n=1097) median age 48 years (range 16-104 years); females (n=903) median age 64 years (range 16-102 years).*

4.1.2 Analysis of trauma mechanisms

Falls were the leading cause of trauma, accounting for 69.4% (n=1387) in all age groups, where the incidence increased with age; the median age of this patient group was 64 years (IQR 88). Within the elderly patient group (≥65 years, n= 752), almost 90.0% (n=676) were injured due to falls.

On the other hand, violent assaults were the second most frequent trauma mechanism in the study group, accounting for 14.7 % (n=294) of the cases, were the median age in this group was 32 years (IQR 32), thus evidently more prevalent in the younger age groups. Also, 44.9% (n=132) of the violent assaults occurred in intoxicated patients.

Unknown cause of trauma accounted for 7.8% (n=158) of the cases and RTAs was reported in 2.0% (n=40) of the cases. The cause of trauma was not reported in 1.4 % (n=28) of the cases. The injury mechanism among the age groups is illustrated in Figure 7.

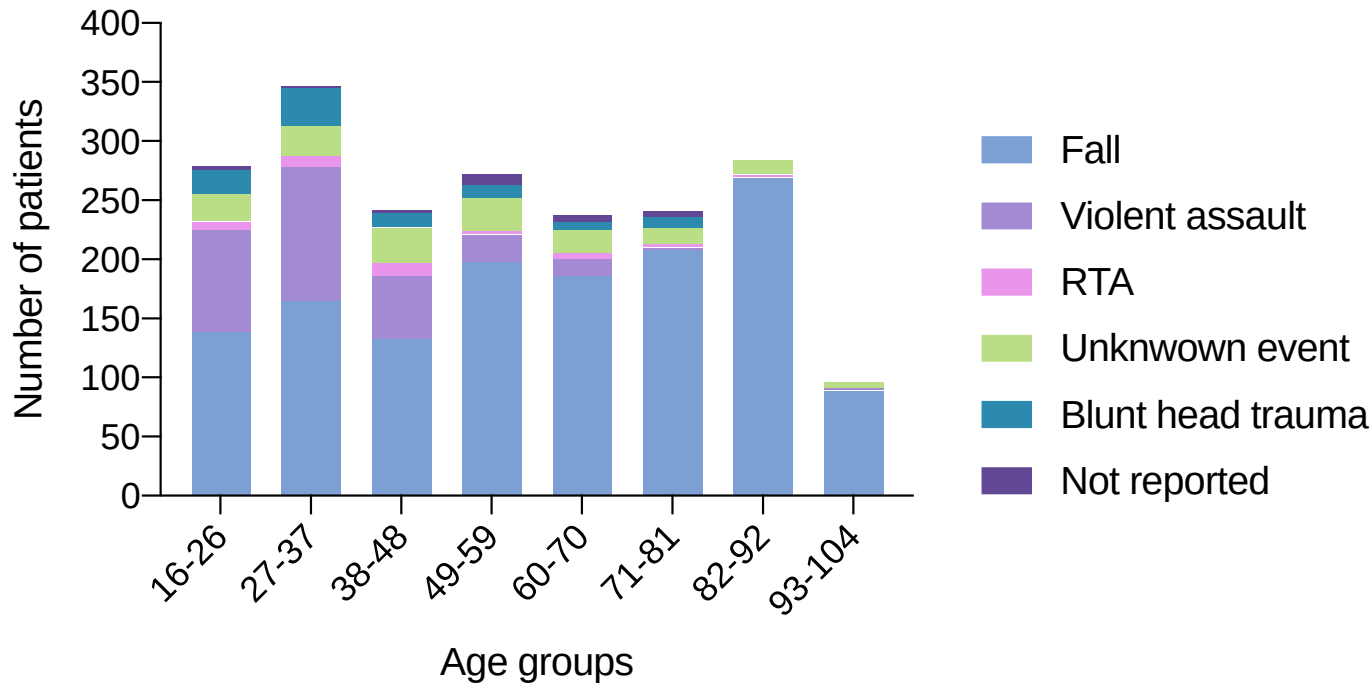

Figure 7 Distribution of injury mechanism among age groups*; Falls (n=1387), violent assaults (n=294), RTA (n=40), unknown event (n=158), blunt head trauma (n=93), not reported (n=28).*

The Chi-square test revealed a significant relationship between trauma mechanism and gender ($X_2(6) = 108.285$, $p = 0.001$). TBI due to violent assaults where considerably more prevalent among male patients (76.5%, n=225). In contrast, falls were most common among females, where 80.2% (n=724) of the female population were injured due to falls (Figure 8).

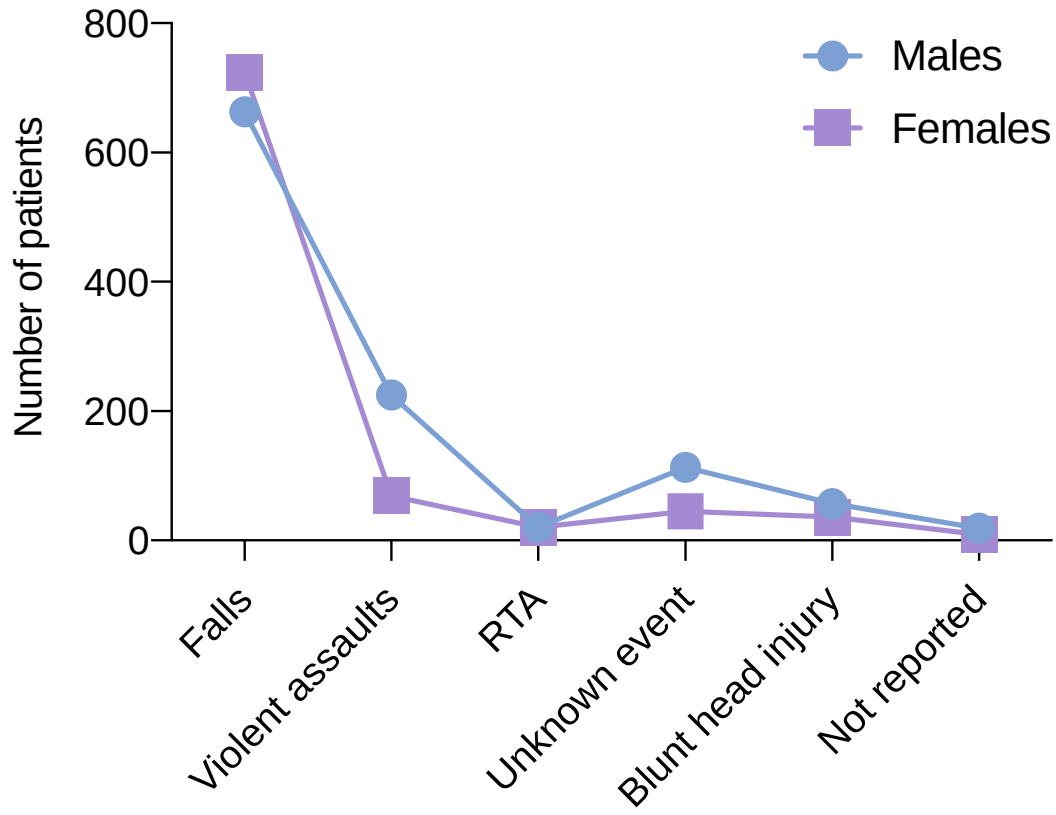

Figure 8 Illustration of injury mechanism among gender*; males (n=1097): falls (n=663), violent assaults (n=225), RTA (n=20), unknown event (n=113), blunt head injury (n=57), not reported (n=19); females (n=903): falls (n=724), violent assaults (n=69), RTA(n=20), unknown event (n=45), blunt head injury (n=36), not reported (n=9).*

4.1.3 Alcohol and drug intoxication

At the time of the injury, 28.8% (n=577) of the overall study group were under the influence of alcohol or drugs, and it was unknown in 21.3% (n=426) of the patients. The median age of the intoxicated patients was 45 years (IQR 29), indicating that it was more prevalent in the younger age groups. Also, 85.3% (n=492) of the patients in the intoxicated group were under the age of 65 years old, which further highlights the age-related trend.

The Chi-square test revealed a significant difference between the number of males and females intoxicated (X_2 (2) =184.9, p=0.001). The reported proportion of males intoxicated was 75.4% and the most common trauma mechanisms within the intoxicated group was falls (n= 337, 58.4%) and violent assaults (n=132, 22.9%). Figure 9 illustrates intoxication among gender and age groups.

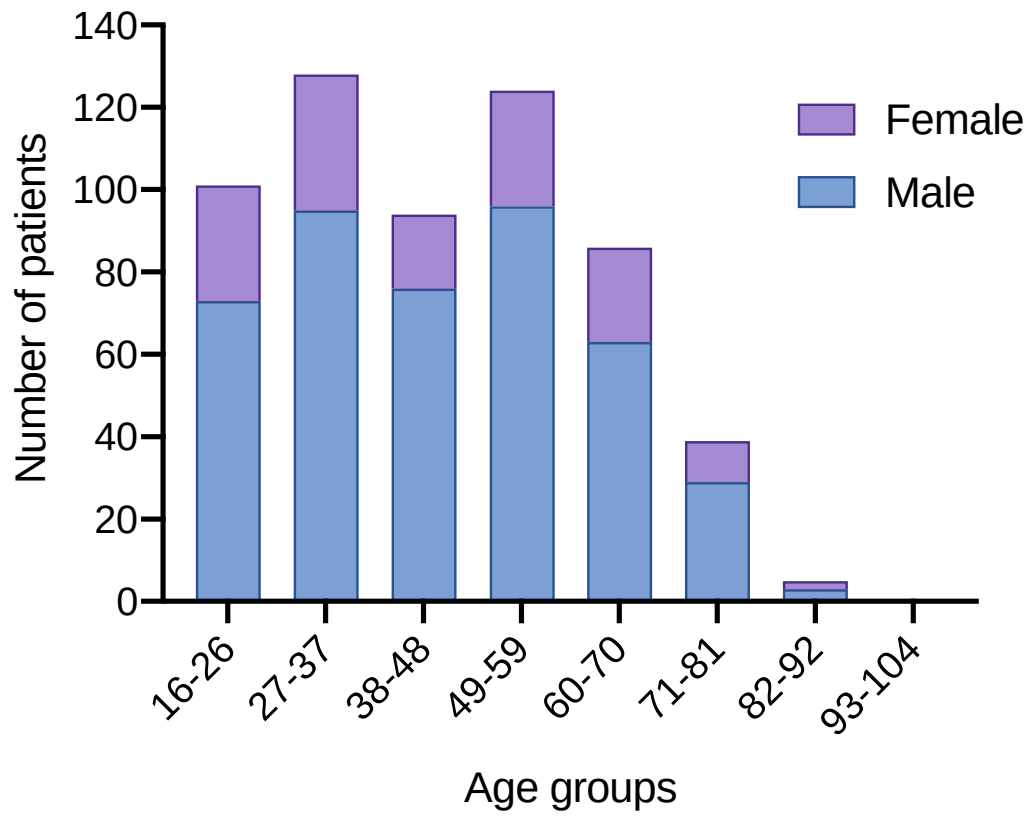

Figure 9 Illustration of intoxication in the study population*: Intoxicated patients (n=577) among age groups; males (n=435) and females (n=142).*

4.2 Data from CT referral form: risk factors and additional clinical variables

4.2.1 Antithrombotic therapy

The overall confirmed use of antithrombotic therapy was reported in 22.0 % of the cases. The median age in the confirmed use of antithrombotic therapy was 82 years (range 30-102) and 54.0% were females. Within the elderly patient group (above 65 years), 50.3% were using antithrombotic therapy. In 41.5% of the study population, this clinical information was unknown (Table 9, section 4.2.2).

4.2.2 Risk factors and additional clinical variables

The majority of the study population, 64.5%, presented with a GCS-score of 14-15, and 3.1% of the patients with a GCS-score below 13. Notably, 67.2% of the patients with a GCS-score below 13 were intoxicated. On the other hand, the GCS-score was not reported in 32.5% of the patients and were defined as unknown GCS-score (Table 9).

At presentation, clinical variables defined as risk factors by the SNC guidelines (47) were reported; confirmed loss of consciousness was reported in 30.8% of the study population, whilst suspected loss of consciousness was reported in 43.7% of the cases. Emesis and gagging were reported in 6.5%. Additionally, focal neurological deficits and post-traumatic seizures were recorded in 2.1% and 0.4% of the cases respectively (Table 9).

Table 9 Presence of risk factors and clinical variables: *variables present in the TBI study population (n=2000), retrieved from CT referral forms*

Clinical variables	Number of patients
Antithrombotic therapy	
Confirmed use	439 (22.0%)
Unknown	829 (41.5%)
GCS-score	
GCS-score 14-15	1289 (64.4%)
GCS-score<13	61 (3.1%)
Unknown GCS-score	650 (32.5%)
Risk factors	
Confirmed LOC	616 (30.8%)
Suspected LOC	873 (43.6%)
Emesis and gagging	129 (6.5%)
Focal neurological deficit	43 (2.1%)
Post-traumatic seizures	9 (0.4%)
Shunt-treated hydrocephalus	6 (0.3%)

GCS: Glasgow coma Scale-score, *LOC*: loss of consciousness. Note: patients may be present in several variables

Additional clinical variables in terms of symptoms including headache and amnesia were also recorded (Table 10). In comparison with the guideline defined risk factors, these symptoms occurred more frequently in the study population.

Headache was the most prevalent symptom, reported in 21.5% of the patients, followed by amnesia (11.8%). A combination of symptoms was recorded as a separate variable, mainly including amnesia and headache combined, and was reported in 5.2% of the patients. Patients with no symptoms reported was observed in 43.1% of the cases.

Table 10 Additional variables: *Presence of additional clinical variables in the study population following TBI*

Additional clinical variables	Number of patients
Headache	430 (21.5%)
Amnesia	235 (11.8%)
Combination of symptoms [a]	103 (5.2%)
Others [b]	184 (9.2%)

[a] Symptoms included combinations of amnesia, headache and dizziness
[b] Other symptoms included falls due to generalized tonic-clonic seizures, syncope, somnolent, altered behavior or difficulty in obtaining anamnesis due to patients' condition.

4.2.3 Classification according to the SNC guidelines and guideline compliance

Based on the presence of risk factors and GCS-scores described in the previous section, the study population was classified into categories defined by the SNC guidelines (47); *minimal*, *mild* and *moderate*.

As the GCS-score was unknown in 32.5% of the patients, and because it is a crucial clinical variable for accurate TBI classification (47), it was impossible to accurately determine the TBI category in these cases. Based on the available GCS-scores, the possibility of imputation of missing variables in this patient category was explored. However, as a consequence of the large amount of missing data, this was not done in order to avoid making bias assumptions (122-124). These patients were evaluated based on the presence of risk factors and categorized according to the presumed SNC classification.

Hence, the study population was divided into two groups; classifiable which included patients with all relevant data present, and non-classifiable where the presumed SNC category was applied (Table 11).

***Table 11 SNC guideline classification**: Classification of the study population (n=2000); classifiable (n=1350) with definite SNC classification and non-classifiable (n=650) with presumed SNC guideline classification.*

SNC guideline category	Classifiable N= 1350	Non-classifiableΩ N= 650
Minimal	165 (12.2%)	72 (11.1%)
Mild low risk	757 (56.0%)	357 (55.0%)
Mild medium-risk	297 (22.0%)	179 (27.5%)
Mild high-risk	70 (5.1%)	42 (6.4%)
Moderate	61 (4.5%)	0 (0.0%)

Ω Presumed SNC category based on the presence of risk factor(s)

In order to assess guideline compliance, the use of CT in each category was evaluated as either correct use or overtriage, leading to guidelines implied compliance and non-compliance respectively.

All patients in the mild and moderate category, a head CT is recommended according to the guidelines (47) and indicated compliance. Definite compliance with the guidelines was seen in 88.2% (n= 1763) of the patients. In the minimal category, the SNC guidelines recommends direct discharge without a head CT, and a head CT in this category indicated overtriage. Thus, non-compliance and was seen in 11.8% (n=237) of the patients.

In total, correct application of the SNC guidelines to this study population would have resulted in a CT reduction of 13.4% (237/1763 patients).

4.3 Data collection from radiology report: imaging findings and management

4.3.1 Head CT

Positive head CT was reported in 110 patients (5.5%). These findings mostly consisted of t-SAH (n= 36, 32.7%) and SDH (n= 32, 29.0%). Combination hemorrhages were reported in 11.0% (n=11) of the patients, which mainly consisted of t-SAH and contusions. Skull fractures without any hemorrhage was reported in 9.1% (n=10) of the patients. The positive head CT findings are illustrated in Figure 11.

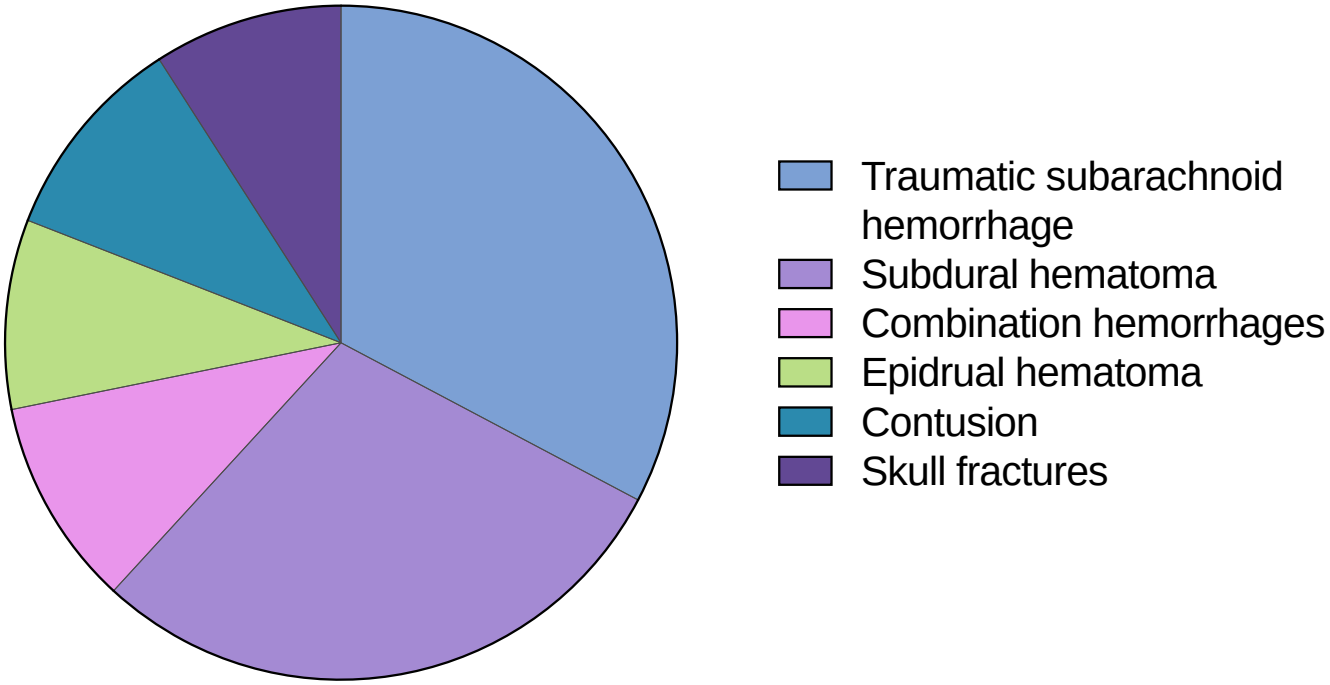

Figure 10 Illustration of the positive CT findings*; traumatic-subarachnoid hemorrhage (n=36), subdural hematoma (n=32), combinational (n=11), epidural hematoma (n=10), contusion (n=11), skull fractures (n=10).*

The largest proportion of the patients with positive head CTs were categorized as mild low-risk (n=58), followed by mild medium-risk (n=32). The minority of the patients where categorized as minimal and moderate categories (n=6 for both). Figure 12 illustrates the patients with a positive head CT and the relevant SNC guideline category.

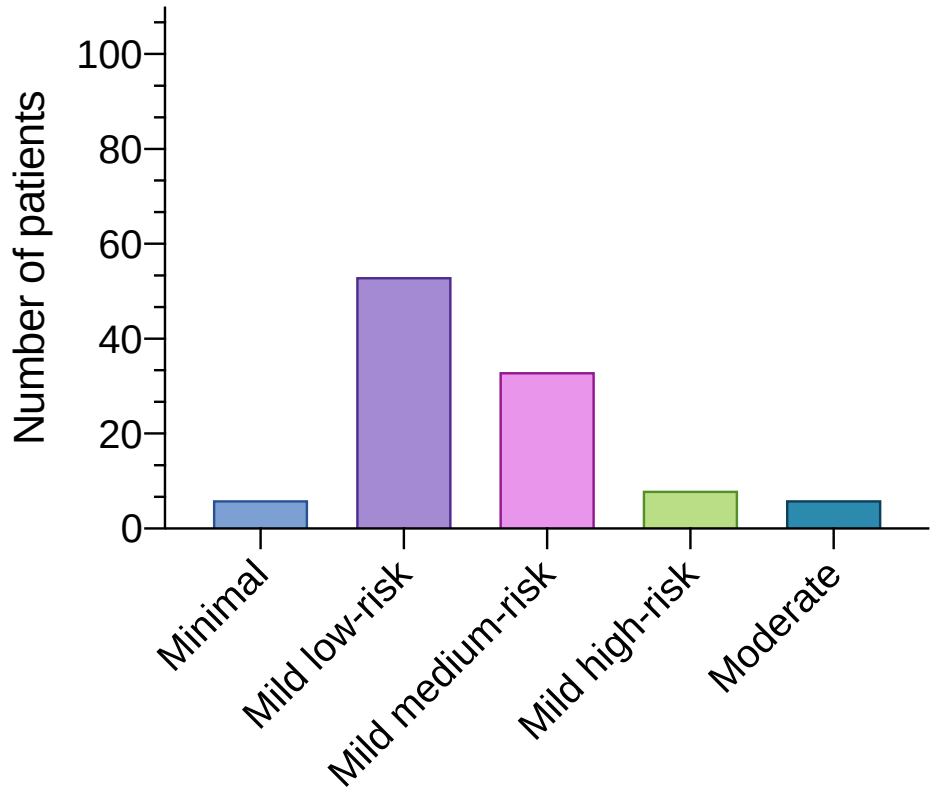

Figure 11 Classification of patients with positive head CT: *patients (n=110) and their respective SNC guideline category; minimal (n=6), mild low-risk (n=58), mild medium-risk (n=32), mild high-risk (n=8), and moderate (n=6).*

Of the patients with a positive CT scan, 72 (65.4%) underwent one or more control head CTs, defined as non-surgical intervention. Table 12 demonstrates the neurocranial injuries and the frequencies of control CTs; this does not include the patients who underwent control CT after neurosurgical intervention (presented in section 4.3.3).

Table 12 Non-surgical intervention: *Patients requiring non-surgical intervention (control CT) (n=72) following a positive head CT*

Head CT finding	**Non-surgical intervention N=72**
Traumatic subarachnoid hemorrhage	22 control CT
Subdural hematoma	21 control CT
Combined	10 control CT
Epidural hematoma	7 control CT
Contusion	6 control CT
Intracerebral hemorrhage	3 control CT
Skull fracture	3 control CT

4.3.2 Positive head CT and risk factors

The Chi-square test showed there was a significant correlation between trauma mechanism and a positive head CT (X_2 (5) = 14.5, p=0.01. Falls accounted for 78.2% (n=86) of the trauma mechanism within the positive head CT group whilst violent assaults and unknown trauma event were both reported in 9.1% (n=10) of the cases, respectively.

The association between each clinical risk factor and variables with a positive head CT was evaluated by the Chi-square test, followed with a Post-hoc test (adjusted standardized residual analysis). GCS 14 (X_2 (2) = 5.4, p= 0.04) and GCS 15 (X_2 (2) =6.8, p= 0.01) were associated with a positive head CT. Further, confirmed loss of consciousness (X_2 (2)= 6.8, p= 0.02), headache (X_2 (2) = 8.0, p= 0.05), age group 16-30 years (X_2(2) =7.7 p= 0.01), and age group above 65 years (X_2(2)= 7.6, p= 0.01) were significantly associated with a positive head CT. Although not statistically significant, a notably large proportion of the patients experienced amnesia as a clinical symptom (18.2%) (Table 13).

Neither anticoagulation use, emesis, focal neurological deficits, post-traumatic seizures nor intoxication were associated with an abnormal head CT.

Table 13 Clinical variables and positive head CT: *Association of clinical variables and positive head CT (n=110). Analysed with Chi-square test with Post-Hoc testing and Bonferroni adjusted p-values.*

Clinical finding	**Number of positive CTΩ**	***p*-values**
Risk factors		
GCS 15	63 (57.2%)	0.041*
GCS 14	12 (11.0%)	0.019*
Confirmed LOC	46 (41.8%)	0.020*
Suspected LOC	47 (42.7%)	0.841
Anticoagulation therapy	24 (21.8%)	0.738
Focal neurological deficits	4 (3.6%)	0.925
Post-traumatic seizures	2 (1.8%)	0.375
Emesis and gagging	9 (8.2%)	0.322
Additional variables		
Amnesia	20 (18.2%)	0.343
Headache	12 (10.9%)	0.051*
Intoxication	41 (37.3%)	0.221
Age group 16-30	12 (10.9%)	0.015*
Age group 31-64	43 (39.1%)	0.675
Age group ≥65	55 (50.0%)	0.017*

Note: Ω Patients may be included in multiple clinical variables
GCS: Glasgow Coma Scale-score; *LOC*: loss of consciousness
*Indicated a statistically significant *p*-value (adjusted with Bonferroni correction).

4.3.3 Traumatic intracranial findings requiring neurological intervention

Only 5 (0.25%) of the 2000 patients with a positive head CT required neurological intervention. Three patients with SDH and two patients with EDH underwent neurosurgical interventions due to their respective lesions. The median age of the patients was 68 years (23-92 years), where 3 out 5 patients were females.

All of the patients had a GCS-score of 15; one patient presented with confirmed loss of consciousness and amnesia as clinical symptom (mild low-risk). Further, two patients had suspected loss of consciousness (mild low-risk), where one of the patients presented with

repeated emesis and the latter had no reported symptoms or risk factors. The remaining two patients presented with no loss of consciousness, where one patient presented with focal neurological deficits as a risk factor (mild high-risk) and the other presented with headache as the only clinical variable (minimal). None of the patients had confirmed use of antithrombotic therapy. The patients were classified in relation to the defined SNC guideline categories; 4 out of 5 were classified as mild TBI and one was classified as minimal TBI (Table 14).

Table 14 Neurosurgical intervention: *Individual patients requiring neurosurgical intervention (n=5), with head CT finding and SNC guideline classification*

Patient	Head CT finding	Neurosurgical intervention	SNC guideline classification
1	EDH and cranial fracture	Cranioplasty and evacuated hematoma	Mild low-risk
2	EDH and bilateral cranial fracture	Craniectomy	Mild low-risk
3	SDH (subacute)	External ventricular drain	Mild low-risk
4	SDH (subacute)	Trepanation (burr hole)	Mild high-risk
5	SDH (subacute)	Trepanation (burr hole)	Minimal

EDH: Epidural hematoma; *SDH*: Subdural hematoma

4.3.4 Missed bleeds and incidental findings

Of the 110 patients with a positive CT, 10 bleeds were missed by resident radiologists and detected after double-reading. They consisted of subtle t-SAH and contusions. None of the patients required any neurosurgical intervention and only 5 patients received control head CT.

Incidental pathological findings were found in 4.3% (n=87) of the patients. The most significant findings included tumor (n=15), cerebral stroke (n=14) and aneurisms (n=3).

4.3.5 Multiple head CTs

In order to get an overview of the number of patients receiving multiple head CTs, we documented the amount of head CTs preformed during the past 5 years. There was a total of 401 (20.1%) patients that had more than one head CT preformed in the past 5 years, ranging

from 2 to 24 head CTs. The median age among these patients was 54 years (range 19-100 years), and 58.6% were male. The number of positive head CTs in this group was 3.0% (n=12). Additionally, among this patient group, 34.7% were intoxicated.

A further analysis of this patient group revealed that 20.0% of the patients underwent more than 5 head CTs in the same five-year period.

5.0 Discussion

5.1 Clinical variation and demographics

This study describes a six-month cohort of TBI patients who obtained a head CT at the OED, with respect to demographics, injury severity, trauma mechanism, positive head CT and neurosurgical intervention. An assessment of guideline compliance at the OED was also performed.

5.1.1 Age and gender

There has been an apparent change in the epidemiological patterns of TBI patients, where previously it was described to be more prevalent in younger patients (117, 125). Several recent European epidemiological TBI studies have described an increase in age among TBI patients (6, 12, 126). Peeters et al. (6) conducted a meta-analysis of 28 studies, where the reported mean age varied from 22 years to 49 years. Despite the variation in the mean age, the authors concluded and highlighted the increase of TBI in the elderly. This was in alignment with another recent European (126) and Norwegian epidemiological study (12), where the reported mean age was 44.5 and 46.7 years respectively.

The median age in our study was 54 years and although it was slightly higher compared to the previously mentioned epidemiological TBI studies, the results adds to the conclusion of a change in epidemiological patterns. This age shift in TBI studies is most likely a reflection of an overall increase in the mean population age, resulting in a higher incidence of TBI in the elderly population (44, 117). However, it must be emphasized that the findings in our study are from an ED, where the majority of the patients are minimal, mild and moderate TBI cases. As the severe cases do not present to the OED, the higher age in this present study may reflect the relationship of TBI severity and age, where severe TBI occurs far more frequent in the younger age groups (12). Additionally, the median age varied between the genders in our study, where females median age was higher than of men; 64 years and 48 years respectively.

The reported proportion of males is slightly greater than females in this study, with a male-to-female ratio of 1.2:1.0. A recent European TBI meta-analysis reported similar results, although the reported male-to-female ratio ranged from 1.2:1.0 to 4.6:1.0 (6). A possible reason for why there are more male TBI patients compared to females, may be as a result of the most frequently occurring causes for TBI; violent assaults and RTAs are more male-dominating activities (126). This was evident in our study as well, 76.5% of the cases of violent assaults occurred in the

male population, which seemingly increases the male ratio.

However, the proportion of men in our study decreased with age, where females accounted for 58.2% of the patients above 65 years of age. Similar to other TBI studies, where females commonly dominate the older age groups (6, 126, 127). A natural explanation for this is the dominating female ratio amongst the elderly population in general, and needless to say reflects this same trend in TBI patients.

5.1.2 Comorbidities

Comorbidities tend to increase with age and older patients often presents with multiple pre-injury comorbidities (117). With regards to TBI, one of the most important comorbidities are antithrombotic therapy and platelet aggregation inhibitors. These are usually prescribed to older patients for both treatment and preventative measures for different illnesses (128).

The overall use of antithrombotic therapy was reported in 22.0% of the patients in our study. Within the patient group above 65 years of age, 50.3% of the patients were using antithrombotic medication. Similar results have been reported in previous studies, where the antithrombotic use ranged from 33-45% among elderly patients (52, 129, 130). The use of antithrombotic therapy and other anticoagulants are often associated with an increased risk of traumatic intracranial hemorrhage and a secondary progression of the hemorrhage, where these medications act as an aggravating factor (131).

Although antithrombotic therapy has been included as a risk factor in some clinical guidelines (47, 70), others have not been validated for this variable (15, 16). Adding to the difficulty and confusion for both the physician and institution on the appropriate assessment of patients using antithrombotic or antiplatelet therapy with regards to TBI (48). Some studies have shown an increased risk of post-injury complications particularly for the patients on antiplatelet drugs such as warfarin, aspirin and clopidogrel (132, 133).

As the TBI population has encountered a newcomer of older adults, where the use of antithrombotic medication is relatively high, there may be a need for additional considerations in this patient group for optimal clinical assessment and avoiding unnecessary head CTs. As for the SNC guidelines, patients above 65 years and using antiplatelet therapy (such as aspirin and clopidogrel) are classified as mild-risk patients, whilst patients using anticoagulation therapy (such as coumadin and warfarin) are classified as mild high-risk; both categories are recommended a head CT according to the guidelines (47). However, as it was evident in our study and prior studies, the changing epidemiological pattern may result in a relatively high

amount and an increase in head CTs due to this newcomer. Interestingly we found no significant correlation between positive head CT and the use of antithrombotic or antiplatelet therapy. It could be argued that maybe this comorbidity alone, should be reconsidered as a risk factor in minimal, mild and moderate TBI patients, though more research is required regarding this.

In the vast majority of TBI research, the elderly tends to be under-represented, often due to strict inclusion criteria, where pre-injury comorbidities are often an exclusion criteria. This often results in limited understanding of TBI outcomes for the elderly population (36). With this shift in the epidemiological pattern of TBI towards elderly (6, 117), some studies have expressed concern that GCS-score does not reflect the severity of injury accurately in the elderly population, especially with comorbidities such as pre-existing dementia (36, 134). Thus, there is a need for focused research and facilitate increased awareness to improve the diagnosis and hopefully outcome in this patient group. A separate set of guidelines for this patient group might be of interest.

5.1.3 Trauma mechanism

Several studies suggest there has also been a shift in trauma mechanism over the last decades, as epidemiological studies from the early 2000 reported RTAs to be the leading cause of TBI, where young males were more predominant (135). Recent studies however, report falls as the leading cause, suggesting a change in the cause of TBI over recent years (6, 127). A possible explanation for this may be the vast development of preventative measures and increased road safety awareness over the past decades, resulting in less RTA related TBI (12, 44). This is however not the case for low-income countries, where RTAs is still the leading cause of TBI, possibly due to inadequate implementation of traffic safety regulations and traffic education (117)

Even so, RTAs are still reported as the leading cause of severe TBI (6, 12, 127). Severe TBI only accounts for approximately 8% of TBI cases and occurs with far less frequency than the mild and moderate TBIs, which could be the reason why it is not as common of a trauma mechanism (5). Incidentally, RTAs only accounted for 2.0% of the TBI cases in our study. With that being said, OED, as mentioned before, rarely to ever encounter severe TBIs or multi-trauma patients, which usually encompasses RTAs and could be an explanation for this low percentage.

Our results are in keeping with the trauma mechanism shift of falls being the most common. They accounted for almost 2/3 of the trauma mechanisms (69.4%) in all age groups. Falls were especially common in the elderly patient group (≥65 years), where nearly 90.0% of the trauma mechanisms were due to falls. Similarly, a recent European multicentre TBI study (CENTER-TBI) reported that falls were the most frequent cause for TBI and increased with age (127). Again, a reflection of the increase in age in the overall population, particularly of developed countries (12, 117).

Although falls and RTAs are the leading causes of TBI in previous studies, violent assaults were the second most frequent cause of TBI in our study, which accounted for 14.7% of the cases. Males were more susceptible to this trauma mechanism, accounting for 76.5% of the violent assault cases (p=0.001). Results from a recent Norwegian hospital-based epidemiological study, reported that assaults were more common in highly populated areas, which is the case for Oslo (12). Also, 44.9% of all violent-related cases in our study patients were intoxicated, which may be a possible explanation for this trauma mechanism being the second most frequent.

5.1.4 Alcohol and drug intoxication

Alcohol or drug intoxication was reported in 27.8% of the overall proportion, which is in keeping with previous Norwegian studies (78, 136, 137) and European studies (127, 138) who report similar results of substance consumption in TBI patients, ranging from 25% to 35%. Although this was common among all age groups, the vast majority of this group (85.2%) were under the age of 65.

Falls and violent assaults were the most common trauma mechanisms among intoxicated patients and accounted for 58.4% and 22.9%, respectively. This finding is in agreement with other Nordic studies (12, 136, 139).

Interestingly no guidelines have this variable in their decision algorithm. This is a very difficult patient group to assess as substance consumption may influence the level of consciousness, making the clinical evaluation and hence guideline assessment difficult. As this study shows, as well as others, this can lead to unnecessary use of diagnostic resources and potentially a high number of avoidable head CTs.

Surprisingly, 34.7% of the intoxicated patients had more than one head CT preformed within the previous 5 years. The number of head CTs ranged from two to twenty-four head CTs for individual patients. Although the extreme amount of head CTs were limited to a few patients,

it is indicated that intoxicated patients may to some extent be susceptible to a high number of unnecessary head CTs.

Alcohol and drug intoxication are well-known risk factors for the incidence of TBI (47, 137, 140). Our study revealed 7.1% of the intoxicated patients had a positive head CT, accounting for nearly 40% of the positive findings. One study has reported that the severity of TBI varies depending on whether it is a case of acute substance use or if there is known pre-injury substance abuse (137). TBIs was reported to be less severe in acute substance use often caused by low-energy traumas, whereas pre-injury substance abuse is associated with increased severity of TBI. Unfortunately, this present study was unable to differentiate between these two entities. However, it is clear from this that the severity of TBI and the effects of substance consumption needs to be reliably distinguished, aiming to avoid over- and under-triage of these patients.

5.2 Guideline compliance and possible reasons for non-compliance

Several evidence-based guidelines exist, with the aim to guide the physicians in appropriate use of CT, in order to identify and distinguish patients with clinically important TBI and thereupon reducing unnecessary head CTs within this heterogenic patient group (72). Despite this, a recent study estimated between 10% to 35% of the head CTs obtained in the ED, are not in accordance with the guidelines (86). The reason for over triage and unnecessary head CTs is not documented, though it has been suggested that the experience of physicians may have an impact (141).

Our results demonstrated that the correct use of head CT was found in 88.2% of the cases, indicating a high rate of guideline compliance. The vast majority of the patients were classified as mild TBI, whilst moderate TBI accounted for a comparatively small amount of the cases. Non-compliance was observed in 11.8% of the patients, classified as minimal TBI, where according to the SNC guidelines, a head CT is not indicated (47).

From this standpoint, the high rate of guideline compliance may be considered as exceptional results. However, it should be emphasized that the majority of the patients in the mild TBI category consisted of mild *low risk*. In this subgroup, the SNC guidelines recommend Serum S100B analysis where available. The aim for using this analysis as a substitute diagnostic tool is to reduce CT imaging, as the risk of developing neurocranial complications in this subgroup of mild TBI category is very low (47). An apparent restriction of this recommendation is the availability and accessibility; not all EDs, including the OED, have readily access to this

analysis (108). Hence, a head CT will be performed. The guidelines do not seem to reckon that the high proportion of this patient group and a relatively low incidence of positive head CTs ultimately will lead to over-triaging. However, our results are inconsistent with this concept, where the largest proportion of the patients with a positive head CT, ironically, were classified as mild low-risk patients.

Possible reasons for noncompliance and overtriage of TBI patients have been explored in previous studies. In a Norwegian study conducted by Heskestad et al (77), the authors found a substantial amount of unnecessary head CTs of minimal, mild and moderate TBI. The overall guideline-compliance was reported to be 51%, despite an extensive guideline implementation-process. The authors conducted a follow-up study, where the guideline compliance increased to 64% following an in-hospital intervention process (115). The authors suggested the reason for noncompliance was due to physicians preferring a one-step-decision-making process, where a head CT was ordered before a complete clinical evaluation was done. Secondly the authors suggested that experience of the physicians varies, as it often does in a clinical setting, which may have affected compliance with the guidelines. This reason was also reported in a different study (142), where the authors suggested that defensive medicine, in the context of fear of missed pathology, was a reason for over-triage of TBI patients, resulting in nonindicated head CTs.

However, it is important to highlight that in the aforementioned studies (77, 115) evaluation of guideline compliance was done with both CT use and patient management regarding hospitalization and observation, as the study was conducted in a university hospital with a neurosurgical unit. This was not the case for this present study, as the aim was to assess guideline compliance of head CT usage in an ED setting. This could explain the large differences in guideline compliance reported in the two studies.

The difficulty in assessing noncompliance in this study was the lack of clinical information given to the reporting radiologist. One aspect to note is that at OED, CT is an order rather than a referral to the radiology department. It could be argued that it does not matter what clinical information is included in the referral form, as the CT will be performed regardless. A possible outcome of this, could be the lack of GCS-score in 32.5% of the cases, making a proper assessment of guideline compliance problematic. Although these patients were classified according to their presumed SNC guideline category, the GCS-score is nonetheless a crucial variable to correctly categorize the patients.

As mentioned earlier, our study showed that there was a low level of noncompliance, however a possible CT reduction of 13.6% could have been obtained if the minimal TBI patients who were not recommended a CT in fact did not receive one. Contrarily, of these patients, six had a positive head CT, where one patient required neurosurgical intervention. Though none of the patients had any of the predefined risk factors present, a majority of the patients had headache as a clinical variable; this may raise concern about the applicability of the guidelines in the TBI population.

The exact reason for noncompliance in this study is not known. It is important to note that the majority of the physicians working at the OED are trainee doctors and may lack sufficient clinical experience. Also, the fact that there are no radiologist or neurosurgeons available at the ED, preforming a head CT is more accessible and can be regarded as a safety nett for resident doctors, especially during the nightshifts. Additionally, researchers have suggested that difficulty obtaining proper anamnestic information may lead to physicians ordering otherwise unindicated head CTs (143), which also may have been the case in our study.

Other factors that may affect guideline compliance these days is patient demand, where some authors have reported increase in patient demand on radiological services (63, 142). Other authors have also demonstrated the importance of recognizing the possible barriers to guideline compliance in the wider context of health-care systems; any level of the system including patients, physicians or the organization, may all influence guideline compliance (144). Thus, an absolute guideline compliance may be limited in clinical practice. Developing an evidence-based intervention to improve clinical practice and management of TBI patients have previously shown positive results (145-147).

Maybe due to this heterogeneous group as with the rest of medicine, a more personalized approach should be considered in TBI patients as well, such as personalized guidelines should be considered for the different age groups and intoxicated patients. It is almost next to impossible to stop the vast increase in demand from radiology departments, but on the other hand understanding the importance of the diagnostic reassurance it provides, especially for less experienced resident doctors with the complicated TBI patient group.

5.3 Radiological findings and risk factors predicting positive head CT

In the present study, 5.5% of the patients had a positive head CT following TBI. This rate is similar with prior studies, where the rates of positive head CTs ranged from 5% to approximately 7% (143, 148, 149), although as high as 9.8% have been reported in other studies (74). Studies with higher rates does not necessarily indicate high compliance rates, it could be due to study setting, population, inclusion criteria or they might have limited access to CT.

Although the frequency of positive head CTs are comparable to the aforementioned studies (143, 148, 149), both study-period and study population differed; the study period for the prior studies were longer (ranging from one year to two year) with fewer patients (ranging from 662-1325), whilst we had a shorter study period and far more patients. This confirms our assumption regarding overuse of head CTs at OED.

Like previous studies (149, 150), the most common neurocranial CT finding in this study was SDH and t-SAH. The SNC defined risk factors significantly associated with a positive head CT were GCS-score of 15-14 (p=0.004, p=0.019, respectively) and confirmed loss of consciousness (p=0.02). Neither use of anticoagulation therapy, emesis, focal neurological deficits nor other risk factors defined by the SNC guidelines were significantly associated with a positive head CT. Interestingly, age groups 16-30 years and patients above 65 years were significantly associated with a positive head CT (p= 0.015 and p= 0.017, respectively).

The additional clinical variable, headache, which is not defined by the SNC guidelines as possible predictors of a positive head CT, was significantly associated with a positive head CT (p= 0.05). Although not statistically significant, amnesia as a clinical symptom was highly prevalent in the positive CT group, reported in 18.2% of the patients. The decision of including additional clinical variables may have captured the heterogeneity of the TBI group. The fact that a large proportion of the patients presented with clinical variables other than the predefined risk factors, may have aided in capturing the rather limited risk factors defined by the guidelines, which again reflect the challenges of categorizing the heterogeneous group TBI patients represents.

5.3.1 Patients requiring neurosurgical intervention

The proportion of patients with a positive head CTs requiring neurosurgical intervention in the present study was 0.25%, which is in agreement of previously reported studies where neurosurgical interventions are included as an outcome (143, 149). The reason for a low number of patients requiring neurosurgical intervention is probably due to this cohort´s vast majority of minimal and mild TBI patients. Neurosurgical intervention is more predominant in severe TBI, and these patients are often directly transferred to a hospital with an available neurosurgical unit (112, 113).

With the SNC guideline categories in mind, surprisingly patients requiring neurosurgical intervention were in the mild TBI group, and none in the moderate group. It is the moderate group that have a higher risk of neurocranial injuries (47). On the other hand, almost two-thirds of the patients in the moderate group were intoxicated; implying that the GCS-score might not reflect the true clinical severity.

There are disputes whether the need to identify neurocranial injuries that do not require neurosurgical intervention is of importance (149). While most guidelines´ purpose is to identify the injuries requiring neurosurgical intervention (125), solely addressing this as the main outcome may be considered too restrictive. Although long-term sequalae may occur as result of nonsurgical neurocranial injuries, it is rare and there is uncertainty of the advantage of early treatment (151). Even though most patients will make full recovery following minimal and mild TBI, 15-25% report post-concussion symptoms (146). Also, studies indicate that there may be an increased risk of post-traumatic headache and other conditions, that may have an adverse effect among patients with intracranial hemorrhages (152). Thus, it is argued that it is valuable to identify these patients early, in order to improve patient care and individual outcome (125).

Another aspect regarding clinical guidelines, although they are evidence-based, the guidelines are often based on data gathered more than 20 years ago (15, 16, 70). Because of changing epidemiological pattern regarding aging patients and trauma mechanism, it could be argued that guidelines based on more recent data could be more accurate (125). In addition, due to technology development, CT machines are becoming more accurate in diagnosing pathology. Consequently, small and perhaps non-clinically important bleeds such as t-SAH are diagnosed to a greater extent. As an only finding, these bleeds are often associated with less severe injuries and seldom to never progress to life-threatening bleeds (153). Even though there may not be

any direct clinical implications for these patients, here in Norway all patients with traumatic intracranial bleeds, regardless of their clinical implication, lose their drivers licence for six months (111). This can have huge implications for young working patient dependant on their car to execute their job.

5.4 Missed bleeds and incidental findings

There was only 10 missed cerebral hemorrhages by residents, which is only 0.5% of the total 2000 head CTs. This is miniscule. None of these had any acute clinical implications and mainly consisted of t-SAH and small contusions; only 5 of the patients had a repeat control head CT.

Double reporting is a routine practice for all radiology residents in Norway (119), however in a patient group like this, potential exceptions could be made to where experienced residents could sign themselves. There are however no reported studies where this has been done.

With all performed radiological scans, a number of incidental findings will always arise. The incidental findings in this cohort were 4.3%, where 32 of these 84 patients required further investigations. These included cases of tumours, cerebral stroke and aneurisms.

Similar results of incidental findings have been reported by other authors (143, 154). While most of incidental findings are considered non-clinically important and benign, other findings require follow-up and close observation (154). The latter may therefore be significant for the individual patient. Though it could be argued that more often than not, these findings will give unnecessary concern for the patients with little clinical and/or management implications. Although debatable, it could be argued that findings that are of clinical relevance will eventually make themselves known.

5.5 Regulars at OED

The Nordic radiation protection authorities (88) have previously stated their concern about the increased number of CT scans, particularly in Norway. Here reports have demonstrated that between 20% and 75% of the diagnostic procedures do not positively influence the patient's management. Recently, the "Choosing Wisely" campaign aimed to reduce the use of unnecessary CT (89, 90).

The findings in our study revealed that a high number of patients received more than one head CT during the past five years; this consisted of 20.1% of the patients, where the number of head CTs ranged from 2 to 24 head CTs. Although it is uncertain to what extent the number of unnecessary head CTs for each individual patient was, only 3.0% of the patients had a positive

head CT, implying that a great proportion of the frequent patients are susceptible to unnecessary head CTs.

As previously mentioned, a large proportion of the patients were intoxicated. These patients are at greater risk for sustaining TBI (47, 155), and could explain the high number of intoxicated patients receiving multiple head CTs. Although the number of radiological exams is available in the radiologic imaging system (RIS), it is uncertain to what extent this is available for the treating ED physicians. A possible solution to this may be to introduce system-reminders for the frequent patients, where the clinicians can evaluate the need for yet another head CT.

5.6 Study limitations

The retrospective design imposes possible issues of bias when collecting data and could be a potential limitation. Also, the data was collected by one person (author), introducing the possibility of human errors during data gathering.

We acknowledge the limitations to solely collect clinical data from the CT referral form. This may have resulted in loss of important clinical information that may have been present in the patient's EHR. Nonetheless, this was done purposely as this method of data collection would result in a comprehensive overview of the available clinical information in the CT referral form. Considering that the radiologist and radiographers rely on adequate clinical information in order to evaluate and validate the use of a CT scan.

We did not distinguish between unknown clinical information due to limited anamnestic information or missing clinical information as it was lacking from the CT referral form. This may have affected the outcome of the study, if we had tried to distinguish between the two from the EHR. This could have been specifically valuable regarding loss of consciousness and antithrombotic therapy, where both are risk factors associated with the TBI severity. Lacking this important differentiation may have decreased the plausibility of the results.

We did not assess guideline compliance regarding patient management (hospitalization and observation). Including this aspect of guideline compliance could have aided in a better understanding of the large amount of patients receiving head CTs. Moreover, we excluded the patients that did not receive a head CT but presented to the OED with a TBI; including these patients could have given a comprehensive overview of under-triage with CT, i.e. direct discharge without CT.

Lastly, the results in this study represents a single institution experience and hence may only reflect the local demographical patterns, thus perhaps the results of this study are not generalizable.

6.0 Conclusion

Analysis of the TBI population and demographics at the OED confirmed our hypothesis regarding the shift of an increase in age and falls being the most important trauma mechanism for minimal, mild and moderate TBI.

Although guideline compliance rate was adequate, the high numbers of head CTs preformed is rather alarming, especially in the context of the small proportion of neurocranial injuries and the miniscule percent that required neurosurgical intervention. More broadly, our results demonstrate the heterogeneity of the TBI patients, and the lack of guideline risk factors present in patients with neurocranial injury. In sight of this, and the constant technological evolution within radiology often resulting in increased detection and characterization of pathology, a responding frequent update on clinical guidelines is imperative. Medicine in general has moved to a more personalized based medicine approach; perhaps this should also be considered in guidelines for TBI patients, and in turn optimizing the management of this heterogeneous patient group.

7.0 Future perspectives

This present study, and previously conducted ones, have shown a gap between clinical practice and guideline recommendations, and it is a known fact that guidelines alone may not aid in better clinical practice. In turn, active strategies targeting to improve clinical practice may aid better recourse allocation and patient management (146).

Implementations we have already made consist of; more structured focused referral forms where all include GCS-score and medication status. Further implementation includes teaching to OED physicians four times a year by neurosurgeons, and twice a year from neuroradiologists, both from OUS-Ullevål. We have also established a more open communication between the three departments (OED, Neuroradiology and Neurosurgical Department), with the aim of a better understanding of clinical practice.

After implementations, a second evaluation will be conducted to assess if there has been a reduction in unnecessary head CTs and if guideline compliance has increased. A more long-term perspective is to tackle the consequence of the small bleeds in neurologically stable patients, such as t-SAH, and the need for control CTs in this patient group, as it is recognized that these bleeds pose little clinical consequence to the patients (156).

Moreover, we are also looking into which anticoagulation medications show progression on control CT; we might not be able to reduce primary head CTs, but possibly the number of control CTs.

Finally, it would be beneficial to conduct a cost-effect analysis to evaluate the benefits and risks of head CTs in this patients group. Though Norwegian based cost-effect studies have been conducted (157), they mostly consisted of severe TBI, which often involves hospitalizations and long-term rehabilitation. A similar study in the ED setting would be far more beneficial in this scenario, as the majority of the cases are minimal and mild TBI.

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Appendix

Appendix 1. Approval from OUS Data Protection Officer (DPO)

Oslo universitetssykehus

Oslo universitetssykehus HF

Postadresse:
Postboks 4950 Nydalen
0424 Oslo

Sentralbord:
02770

Org.nr:
NO 993 467 049 MVA

www.oslo-universitetssykehus.no

TILRÅDING TIL INTERN KVALITETSSIKRING

Til:	Karoline Skogen, overlege KRN AVDELING FOR RADIOLOGI, US/AS
Kopi:	Hans Kristian Pedersen Heidi B. Eggesbø Gunnar Sandbæk
Fra:	Personvernombudet ved Oslo universitetssykehus
Saksbehandler:	Tor Åsmund Martinsen
Dato:	13.07.2018
Offentlighet:	Ikke unntatt offentlighet
Sak:	Personvernombudets tilråding til innsamling og behandling av personopplysninger for intern kvalitetssikring med hjemmel i pasientjournalloven § 6, jf. helsepersonelloven 26
Saksnummer:	18/14057

Personvernombudets tilråding til innsamling og behandling av personopplysninger for intern kvalitetssikring:

«CT caput på Oslo legevakt, når skal det gjøres? Blir det gjort for mange?»

Formål:
Det er en diskrepans på hvor mange CT caput som blir gjort og positive funn samt er det også flere undersøkelser som ikke er klinisk indisert for å ta en CT caput.

Oslo legevakt fikk en CT maskin for å avlaste henvisninger/avklaringer på Ullevål sykehus av potensielle hodeskader. CT caput skulle tas av pasienter hvor avklaring av cerebral blødning er viktig før eventuell utskrivning eller videre behandling. Henvisningene skulle/bør følge retningslinjer for utredning av hodetraume.
Retrospektiv studie: 2000 kliniske CT-undersøkelser fra LV perioden jan 2016 - ca jul 2016.

Vi viser til innsendt melding om behandling av personopplysninger / helseopplysninger. Det følgende er en formell tilråding fra personvernombudet. Forutsetningene nedenfor må være oppfylt før innsamlingen av opplysningene / databehandlingen kan begynne.

Med hjemmel i personopplysningsforskriften § 7-12, jf. helseregisterloven § 36, har Datatilsynet ved oppnevning av personvernombud ved Oslo Universitetssykehus (OUS), fritatt sykehuset fra meldeplikten til Datatilsynet. Behandling og utlevering av helse- og personopplysninger meldes derfor til sykehusets personvernombud.

Personvernombudet har vurdert det til at den planlagte databehandlingen faller inn under pasientjournalloven § 6, annet ledd:

Helseopplysninger i behandlingsrettede helseregistre kan bare behandles når det er nødvendig for å kunne gi helsehjelp, eller for administrasjon, internkontroll eller kvalitetssikring av helsehjelpen.
Ved behandling av helseopplysninger til internkontroll eller kvalitetssikring skal opplysningene så langt som mulig behandles uten at den registrertes navn og fødselsnummer fremgår.

Bruk av helseopplysninger skal skje i samsvar med taushetspliktreglene, jf. helsepersonelloven § 26:
Den som yter helsehjelp, kan gi opplysninger til virksomhetens ledelse når dette er nødvendig for å kunne gi helsehjelp, eller for internkontroll og kvalitetssikring av tjenesten. Opplysningene skal så langt det er mulig, gis uten individualiserende kjennetegn.

Personvernombudet tilrår prosjektet under forutsetning av følgende:

1. Databehandlingsansvarlig er Oslo universitetssykehus ved adm. dir.
2. Avdelingsleder eller klinikkleder har besluttet behovet for kvalitetssikringen.
3. Behandling av personopplysningene / helseopplysninger skjer i samsvar med og innenfor det formål som er oppgitt i meldingen.
4. Data lagres som oppgitt i meldingen. Annen lagringsform forutsetter gjennomføring av en risikovurdering som må godkjennes av personvernombudet.
5. Kryssliste som kobler avidentifiserte data med personopplysninger lagres separat.
6. Oppslag i journal gjøres av ansatte ved sykehuset som har selvstendig lovlig grunnlag for oppslaget. Det vises i denne sammenhengen til beslutning fra leder om behovet for kvalitetssikringen med hjemmel i hpl. § 26 og pjl. § 6.
7. Eventuelle fremtidige endringer som berører formålet, utvalget inkluderte eller databehandlingen må forevises personvernombudet før de tas i bruk.
8. Når behovet for kvalitetssikringen opphører skal data slettes eller anonymiseres ved at krysslisten slettes og eventuelle andre identifikasjonsmuligheter i databasen fjernes. Når formålet med registeret er oppfylt sendes melding om bekreftet sletting til personvernombudet.

Kvalitetsregisteret er registrert i sykehusets offentlig tilgjengelig database over kvalitetsregistre, forsknings- og kvalitetsstudier.

Med hilsen

Tor Åsmund Martinsen
Personvernrådgiver

Oslo universitetssykehus HF
Stab fag, pasientsikkerhet og samhandling
Avdeling for personvern og informasjonssikkerhet

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