

Original Article

Traumatic brain injury in the Central Denmark Region 2014-2021

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ABSTRACT

INTRODUCTION. Traumatic brain injury (TBI) is associated with high morbidity and mortality. The TBI population has changed in recent years. We aimed to characterise TBI patients treated at the major trauma centre in the Central Denmark Region from 2014 to 2021.

METHODS. We conducted a retrospective cohort analysis of patients with TBI admitted by trauma team activation from 2014 to 2021. Patients were stratified according to the Abbreviated Injury Scale into mild TBI (mTBI), moderate to severe TBI (sTBI) and polytrauma TBI (pTBI).

RESULTS. A total of 1,543 consecutive adult TBI patients were included. The median age peaked in 2021 at 55 years, and the proportion of patients aged ≥ 65 years was 31.9%. In 2021, the incidence of sTBI was $7.8/10^5$ inhabitants, and the incidence of pTBI was $3.1/10^5$ inhabitants. From 2014 to 2021, the 30-day mortality of mTBI, sTBI and pTBI remained unchanged at 1.7%, 17.5% and 25.5%, respectively. During the study period, patients aged ≥ 65 years with sTBI and pTBI had an odds ratio for 30-day mortality of 4.98 and 2.23, respectively, compared to patients aged 16-64 years. In the entire cohort, road traffic collision was the most common mechanism of injury for mTBI (28.1%) and pTBI (28.8%), and fall injuries was the most common mechanism of injury for sTBI (43.3%).

CONCLUSIONS. The median age and the proportion of elderly TBI is rising. From 2014 to 2021, the 30-day mortality of mTBI, sTBI and pTBI remained unchanged at 1.7%, 17.5% and 25.5%, respectively. Fall injuries cause more than a third of all TBI.

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TRIAL REGISTRATION. The Central Denmark Region and the Hospital Board of Directors approved the study (reference 1-16-02-339-23).

Traumatic brain injury (TBI) is a leading cause of morbidity and mortality among adults and constitutes a considerable public health burden [1, 2]. In Europe, TBI caused 1.5 million annual hospital admissions and had an age-adjusted mortality of $11.7/10^5$ inhabitants [1]. The incidence and mortality differ substantially between countries [3]. A large multicentre study (the CENTER-TBI study) investigated TBI in 18 European countries during the 2014-2017 period [2]. The study included 4,509 patients and found the European TBI population to have increasing age, more frequent fall injuries and a growing level of comorbidity [2]. However, these large studies found considerable national and regional variations in TBI patients' clinical characteristics, treatment and outcomes [1, 2, 4]. Another finding was the high fraction of patients with mild TBI [2]. Changes in the trauma

patient population over time have been established by multiple studies [2, 5-7]. Furthermore, the incidence and pattern of TBI are changing due to the increasing age of trauma patients and a growing number of fall injuries [2]. In addition to previous research, we aim to provide an update on TBI patients received at the major trauma centre in the Central Denmark Region, focusing on demographics, TBI severity, time trends, incidence, mechanism of injury and 30-day mortality.

Methods

This was a retrospective cohort study of 1,543 consecutive adult TBI patients covering an eight-year period (2014-2021) at the major trauma centre of the Central Denmark Region. The study was reported according to the STROBE guidelines [8].

Setting and data collection

The Aarhus University Hospital Trauma Center (AUH-TC) is a tertiary trauma centre with approx. 600 annual trauma team activations. In 2019, 31.1% of these were severe injuries (Injury Severity Score (ISS) > 15) [7]. Approximately 200 (33%) of the trauma team activations are TBI, and more than half of these patients have a moderate to severe TBI (Head-Abbreviated Injury Scale (AIS) score ≥ 3). The Department of Neurosurgery at AUH TC is one of four neurosurgical centres in Denmark. Four regional hospitals transfer patients with TBI requiring neurosurgical observation or intervention to the AUH TC. The catchment area covers the Central Denmark Region with a population of 1.3 million. Trauma team activations are included in the Aarhus University Hospital Trauma Registry (AUH TR).

The prehospital personnel request trauma team activation according to pre-defined criteria ([Table S1, Supplemental Material](#)).

Data in the AUH TR are collected in real time during patients' treatment. Data include patient demographics, injury description, timeline and mechanism of injury. Mechanism of injury is categorised into one of the following categories: road traffic collision, scooter, motorcycle, bicycle, pedestrian, fall, horse, violence, stabbing, gunshot, self-harm, and other mechanisms such as animal-related injuries, crushing, struck by object, machinery accidents or sports injuries. Fall injuries include falls from all heights.

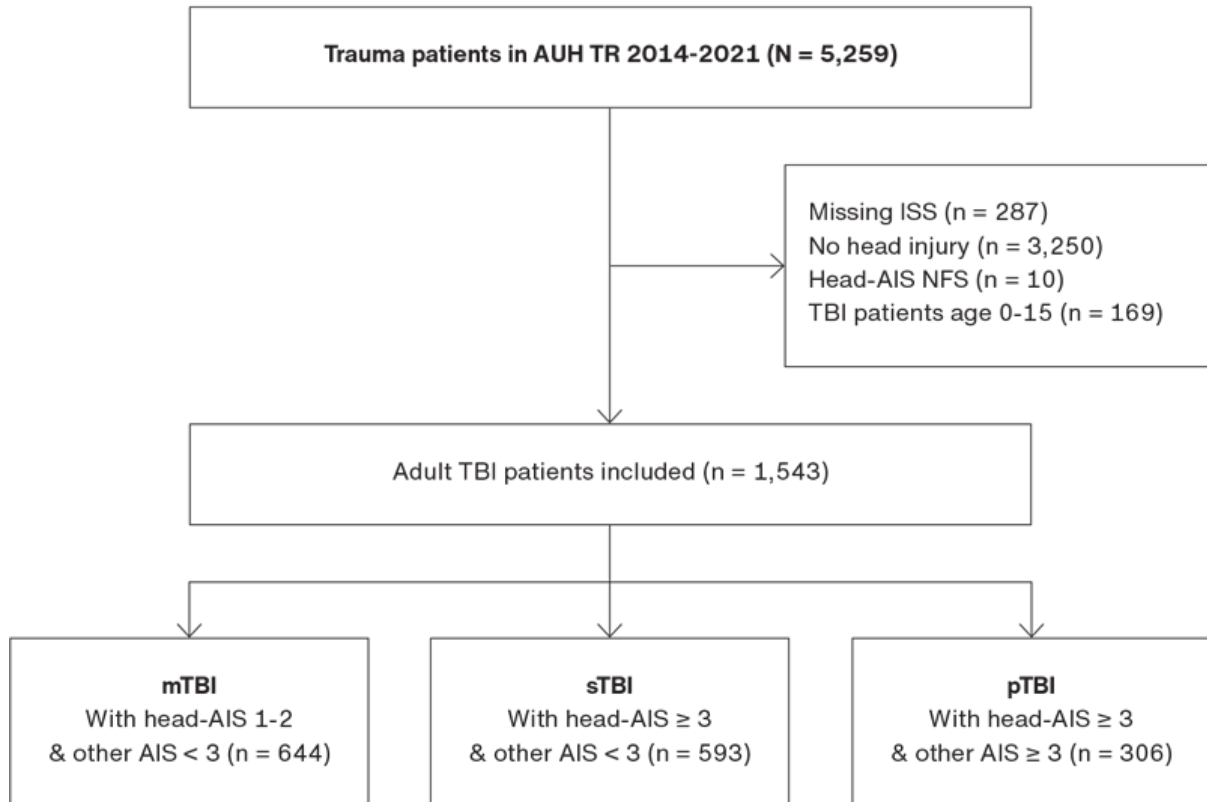
Outcome

Major Danish trauma centres use the AIS to score injury severity. All injuries are coded in the AIS according to risk of death from 1 to 6. Head AIS is the AIS code in the head anatomical region. The ISS and the NISS (New Injury Severity Score) are calculated based on the assigned AIS scores determined by certified personnel. The ISS is calculated based on the AIS score of the three most injured body regions [9], whereas the NISS is calculated based on the three most severe injuries regardless of anatomical regions. Cases and AIS codes are frequently reviewed to ensure consistency. Data for 30-day mortality were retrieved from patients' medical records using the Danish Civil Registration number, which includes the vital status of all inhabitants in Denmark [10].

Patients

TBI patients aged ≥ 16 were included in the analyses. **Figure 1** shows patient inclusion and exclusion for the study. TBI patients were divided into three categories according to TBI severity:

FIGURE 1 Inclusion and exclusion criteria.



AIS = Abbreviated Injury Scale; AUH TR = Aarhus University Hospital Trauma Registry; ISS = Injury Severity Score; mTBI = mild TBI; NFS = not further specified; pTBI = polytrauma TBI; sTBI = moderate to severe TBI; TBI = traumatic brain injury.

1. Mild TBI (mTBI): Head AIS 1-2 and other AIS < 3
2. Moderate to severe TBI (sTBI): Head-AIS ≥ 3 and other AIS < 3
3. Polytrauma TBI (pTBI): Head-AIS ≥ 3 and other AIS ≥ 3 .

Patients with TBI primarily admitted to regional hospitals and with secondary transfer to AUH TC within 24 hours were included. Patients with mTBI treated in the Emergency Department (ED) without trauma team activation were not included.

Statistics

Descriptive data were reported as numbers and percentages. Non-normally distributed data were reported as median and interquartile range. Incidence and mortality rates were calculated using the catchment area population of the Central Denmark Region collected retrospectively at the Danish Statistics website [11]. Multivariate logistic regression analysis for 30-day mortality was calculated for all patients, as were sTBI and pTBI. The year was used as a continuous variable. STATA version STATA/IC 17.0 (StataCorp. 2019. Texas, USA) was used for all statistical analyses. A two-sided p value of < 0.05 was considered statistically significant.

Trial registration: This was a registry study and therefore exempted from trial registration under Danish law owing to the anonymity of the data employed. The Central Denmark Region and the Hospital Board of Directors approved the study (reference 1-16-02-339-23).

Results

During the eight-year study period, 1,543 adult trauma patients with TBI were admitted to the major trauma centre in the Central Denmark Region (Figure 1). Patient characteristics and outcomes are presented in Table 1. Patients with mTBI had a numerically lower proportion of males (65.8%) than patients with sTBI (71.0%) and pTBI (73.4%).

TABLE 1 Patient characteristics, mortality and mechanism of injury of patients with mild, moderate to severe and polytrauma traumatic brain injury attended in 2014-2021.

	mTBI (N = 644)	sTBI (N = 593)	pTBI (N = 306)
Males, n (%)	423 (65.8)	420 (71.0)	223 (73.4)
Age, median (IQR), yrs	43 (27-59)	57 (40-71)	51 (30-65)
Age ≥ 65 yrs, n (%)	124 (19.3)	213 (35.9)	80 (26.1)
ISS, median (IQR)	6 (4-2.5)	17 (13-25)	29 (22-38)
NISS, median (IQR)	8 (4-12.5)	25 (17-34)	34 (27-43)
2nd referral, n (%)	45 (7.0)	129 (21.8)	49 (16.1)
30-day mortality, n (%)	11 (1.7)	104 (17.5)	78 (25.5)
30-day mortality age ≥ 65 yrs, n (%)	9 (7.3)	70 (32.9)	30 (37.5)
<i>Mechanism of injury, n (%)</i>			
Road traffic collision	181 (28.1)	85 (14.3)	88 (28.8)
Motorcycle	22 (3.4)	14 (2.4)	22 (7.2)
Scooter	20 (3.1)	23 (3.9)	17 (5.6)
Bicycle	141 (21.9)	104 (17.5)	46 (15.0)
Pedestrian	23 (3.6)	20 (3.4)	24 (7.8)
Horse	27 (4.2)	5-10 (-) ^a	1-5 (-) ^a
Fall	164 (25.5)	257 (43.3)	78 (25.5)
Violence	19 (3.0)	15 (2.5)	5-0 (-) ^a
Stabbing	10 (1.6)	5-10 (-) ^a	0
Gunshot	1-5 (-) ^a	5-10 (-) ^a	0
Self-harm	5-10 (-) ^a	18 (3.0)	5-10 (-) ^a
Other mechanisms ^b	29 (4.5)	40 (6.8)	17 (5.6)

IQR = interquartile range; ISS = Injury Severity Score; mTBI = mild TBI; NISS = New Injury Severity Score; pTBI = polytrauma TBI; sTBI = moderate to severe TBI; TBI = traumatic brain injury.

a) To ensure the confidentiality of the participants, exact numbers cannot be displayed.

b) Includes crushing, being struck by objects and sports injuries.

From 2014 to 2021, the median age increased from 47 to 55 years for all TBI, from 52 to 64 years for sTBI and from 42 to 57 years for pTBI. The proportion of patients aged ≥ 65 years was numerically higher among sTBI (35.9%) than among pTBI (26.1%). From 2014 to 2021, the proportion aged ≥ 65 years increased for all patients with TBI from 19.6% to 31.9%, for sTBI from 24.3% to 49.4%, and for pTBI from 15.2% to 23.5%. The incidences of sTBI and pTBI are presented in Table 2 and Figure S2.

TABLE 2 Number of patients and 30-day mortality for moderate to severe and polytrauma traumatic brain injury.

Year	sTBI, n	pTBI, n	30-day mortality, n (%)		Population in Central Denmark Region ^a	Incidence (95% CI) ^b	
			sTBI	pTBI		sTBI	pTBI
2014	74	46	11 (14.9)	12 (26.1)	1,034,105	7.2 (5.6-9.0)	4.5 (3.3-5.9)
2015	77	30	13 (16.9)	11 (36.7)	1,041,387	7.4 (5.8-9.2)	2.9 (1.9-4.1)
2016	71	35	11 (15.5)	5 (14.3)	1,052,315	6.8 (5.3-8.5)	3.3 (2.3-4.6)
2017	76	42	8 (10.5)	9 (21.4)	1,063,275	7.2 (5.6-9.0)	4.0 (2.9-5.3)
2018	63	41	10 (15.9)	11 (26.8)	1,072,986	5.9 (4.5-7.5)	3.8 (2.7-5.2)
2019	67	41	15 (22.4)	10 (24.4)	1,080,529	6.2 (4.8-7.9)	3.8 (2.7-5.2)
2020	80	37	15 (18.8)	10 (27.0)	1,087,340	7.4 (5.8-9.2)	3.4 (2.4-4.7)
2021	85	34	21 (24.7)	10 (29.4)	1,093,676	7.8 (6.2-9.6)	3.1 (2.2-4.3)

CI = confidence interval; mTBI = mild TBI; pTBI = polytrauma TBI; sTBI = moderate to severe TBI; TBI = traumatic brain injury.

a) For patients aged ≥ 16 yrs.

b) Calculated per 100,000 people.

Road traffic collision was the most common mechanism of injury in mTBI and pTBI, whereas fall was the most common mechanism of injury in sTBI with 43.3% (Table 1). From 2014 to 2021, the proportion of fall injuries among all TBI patients increased from 27.8% to 36.2% (Table S2, Supplemental Material).

Median NISS was 25 for sTBI compared to 34 for pTBI. No trend in the median ISS or NISS was detected from 2014 to 2021. During the study period, the mean 30-day mortality of mTBI, sTBI and pTBI was 1.7%, 17.5% and 25.5%, respectively. The 30-day mortality for sTBI was 14.9% in 2014 and 24.7% in 2021. (Table 2). During the study period, the crude and age, sex- and NISS-adjusted odds ratio for 30-day mortality remained unchanged for all TBI patients, sTBI and pTBI (Table 3). During the study period, the odds ratio for 30-day mortality of TBI patients aged ≥ 65 years compared to patients aged 16-64 was 4.98 (3.16-7.84) and 2.23 (1.28-3.87) in sTBI and pTBI, respectively.

TABLE 3 Multivariate logistic regression analysis for 30-day mortality of all patients with traumatic brain injury, moderate to severe and polytrauma traumatic brain injury.

	OR (95% CI) [p value]		
	all patients (N = 1,543)	sTBI (n = 593)	pTBI (n = 306)
Age	1.04 (1.03-1.05) [< 0.01]	1.05 (1.03-1.06) [< 0.01]	1.02 (1.00-1.03) [< 0.01]
16-64 yrs	Ref.	Ref.	Ref.
≥ 65 yrs	4.39 (3.21-6.00) [< 0.01]	4.98 (3.16-7.84) [< 0.01]	2.23 (1.28-3.87) [< 0.01]
Sex			
Female	Ref.	Ref.	Ref.
Male	0.87 (0.63-1.20) [0.404]	0.76 (0.48-1.19) [0.227]	0.70 (0.40-1.23) [0.212]
ISS	1.08 (1.07-1.10) [< 0.01]	1.08 (1.05-1.11) [< 0.01]	1.05 (1.03-1.07) [< 0.01]
NISS	1.08 (1.07-1.09) [< 0.01]	1.06 (1.04-1.08) [< 0.01]	1.05 (1.03-1.08) [< 0.01]
Year ^a , 2014-2021	1.03 (0.96-1.10) [0.470]	1.09 (1.00-1.20) [0.060]	1.01 (0.90-1.13) [0.859]
Year ^a adjusted for age, sex and NISS	1.04 (0.96-1.13) [0.298]	1.08 (0.97-1.20) [0.176]	1.00 (0.89-1.14) [0.954]

CI = confidence interval; ISS = Injury Severity Score; NISS = New Injury Severity Score; OR = odds ratio; pTBI = polytrauma TBI; ref. = reference; sTBI = moderate to severe TBI; TBI = traumatic brain injury.

a) Year was used as a continuous variable.

Discussion

This study described the demographics, incidence, mechanism of injury and 30-day mortality of patients with TBI admitted by trauma team activation in the Central Denmark Region from 2014 to 2021. The median age and the proportion of patients aged ≥ 65 years increased in the course of the period and peaked in 2021. The incidence remained unchanged in the period. The proportion of fall injuries increased from 27.8% in 2014 to more than a third of all patients with TBI in 2021. Fall injuries comprised 43.3% of sTBI. The crude and adjusted survival of TBI patients remained unchanged during the study period.

Differences between mild, moderate to severe, and polytrauma traumatic brain injury

Patients with mTBI and sTBI had a lower proportion of males than patients with pTBI (73.4%). This aligns with other studies on pTBI, which showed a 73.1% male pTBI in Israel [12] and 75% in the Netherlands [13]. The median age for mTBI, sTBI and pTBI was 43, 57 and 51 years, respectively. These results are similar to the median age for isolated TBI (57 years) and pTBI (49 years) in the Netherlands [13]. In contrast, the median age was 60 years for isolated sTBI in Germany in the 2013-2017 period [14] and 62 years for TBI patients admitted to intensive care units (ICU) in Finland in 2019 [15].

Changing demographics

In 2021, the fraction of patients aged ≥ 65 years with sTBI and pTBI was 49.4% and 23.5%, respectively. The rising age and proportion of elderly patients with TBI may partly be explained by an increase in life expectancy and mean age from 81.1 to 82.0 years and 40.2 to 41.4 years, respectively, in the Central Denmark Region during the study period [11]. Moreover, the percentage of the adult population in the Central Denmark Region aged ≥ 65 years increased from 21.5% in 2014 to 24.0% in 2021 [11]. Furthermore, the median age of adult trauma patients increased from 37 to 49 years, which is in line with the present study, revealing a steady rise in median age across all TBI severities [7].

The CENTER TBI study included patients with a clinical diagnosis of TBI and indication for CT from 18 countries in the 2014-2017 period [2]. Patients were stratified into groups by their admission type: emergency room, admitted to hospital ward or admitted to the ICU. In this multicentre study, 28% of the population was older than 65 years, and alcohol was a contributory factor in 25% of cases. Comorbidities were present in 43% of the population [2]. CENTER TBI highlighted that the nature of TBI is shifting from young males to older patient with frailty. Additionally, a Norwegian study found the treatment intensity to decrease with higher age and suggested that a focus on treatment on elderly TBI patients would lower mortality [16]. Consistent with the literature, the median age of patients with sTBI is increasing, and elderly TBI patients require more attention than younger TBI patients do.

Mechanism of injury

During the study period, road traffic collisions were most frequent in mTBI (28.1%) and pTBI (28.8%), in contrast to sTBI, which recorded the highest proportion of fall injuries (43.3%). Lecky et al. investigated the burden of low-energy and high-energy falls causing TBI in 2014-2018 [17]. The low-energy TBI cohort had a median age of 74 years compared to 42 years in the high-energy cohort. The low-energy TBI cohort was mostly female and three times more likely to take pre-injury anticoagulants than the high-energy TBI cohort [17]. In the CENTER TBI study, incidental falls were the cause of injury in 46.1% of patients [2]. In the general trauma patient population, the proportion of fall injuries increased from 18.0% in 2010 to 24.4% in 2019 in the Central Denmark Region [7]. Similarly, the present study recorded a rise in the proportion of fall injuries of all TBI severities from 27.8% to 36.6%. Fall prevention is a primary target for reducing TBI burden [2].

Incidence and mortality

In 2021, the incidence of sTBI was 7.8/10⁵ inhabitants, while the incidence of pTBI was 3.1/10⁵ inhabitants. The mortality rate of sTBI was 1.9/10⁵ and that of pTBI was 0.9/10⁵ inhabitants. In Germany, the incidence of sTBI was much higher at 10.1/10⁵ inhabitants in the 2013-2017 period [14]. We found no change in survival during the study period. Likewise, in a neurosurgical ICU in Finland from 1999-2015, adult TBI patients showed no improved 30-day mortality but did record an improved neurological outcome among survivors [18]. In this study, the median age peaked at 60 years, and 60% of TBI patients were due to fall from ground level in 2015 [18]. A national multicentre study from Finland found a decrease in in-hospital mortality and 12-month mortality of TBI patients admitted to ICU from 2003 to 2019 [15]. Overall, temporal improvement in TBI mortality was not detected in the abovementioned studies at neurosurgical centres. However, in a ten-year study of trauma patients at the AUH TC, the ISS and crude 30-day mortality increased from 2010 to 2019, whereas the age, sex and ISS-adjusted 30-day mortality improved in that timespan [7]. In general, patients with TBI admitted by trauma team activation in the Central Denmark Region are older and more often sustain fall injuries than the general adult trauma patient population.

Strength and limitations

This was the first study to investigate patients with sTBI and pTBI received at a major trauma centre in Denmark. The AUH TC admits nearly all patients with sTBI and pTBI in the Central Denmark Region (1.3 million inhabitants). Large studies have a high fraction of mTBI, resulting in a mixed picture when evaluating the sTBI burden [2]. The definitions of TBI severity vary substantially between countries and regions, which challenges comparison. However, the AIS, ISS and NISS account for all injuries and are among the most widely measures used in the research of trauma patients. A limitation is that a considerable fraction of mTBI patients are admitted to the Emergency Department without trauma team activation and were therefore not included in this study. This study only described TBI patients admitted by trauma team activation. The level of under-triage and prehospital deaths remains unknown. Furthermore, this study did not address long-term outcomes. Concomitant injuries may potentially delay TBI treatment. Further research on the aging TBI population, including alcohol, comorbidity, secondary referrals and injury prevention, is warranted.

Conclusions

From 2014 to 2021, the 30-day mortality of mTBI, sTBI and pTBI remained unchanged at 1.7%, 17.5% and 25.5%, respectively. Fall injuries increased during the period, causing more than a third of all TBI. Median age increased from 47 to 55 years in the study period.

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Supplementary material: <https://content.ugeskriftet.dk/sites/default/files/2024-11/a01230042-supplementary.pdf>

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