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Health Care Implications of the COVID-19 Pandemic for Patients with Severe Traumatic Brain Injury—A Nationwide, Observational Cohort Study

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■ BACKGROUND: **Containment measures during the coronavirus disease of 2019 (COVID-19) pandemic have resulted in a substantial reduction in treatment of injury. The effect of the COVID-19 pandemic on the epidemiology and mortality of severe traumatic brain injury on a national, population-based level is unknown.**

■ METHODS: **Data on all patients with severe traumatic brain injury between 2017 and 2020 were retrieved from the National Trauma Registry of Norway. The study cohort was derived from the pandemic period (March 12 to December 31, 2020) and the control cohort from the pre-pandemic years 2017 to 2019. The outcome measures were 30-day mortality, in-hospital mortality, and discharge destination.**

■ RESULTS: **This study included 522 trauma patients with severe traumatic brain injury, 387 (74.1%) in the prepandemic and 135 (25.9%) in the pandemic period. Length of stay increased significantly during the pandemic period (4 vs. 3 days; $P = 0.014$). The 30-day mortality rate was 39% ($n = 149$) in the prepandemic versus 38% ($n = 52$) pandemic period ($P = 0.998$). In-hospital mortality was 33% ($n = 128$) in the prepandemic versus 33% ($n = 44$) in the pandemic period ($P = 0.920$). There were no statistically significant differences in discharge destination besides the number of patients discharged to home in the pandemic period ($P = 0.003$). When adjusted for clinical relevant factors such as age, gender, and head injury severity, the mortality outcomes did not change during the pandemic period.**

■ CONCLUSIONS: **The containment and lockdown measures during the COVID-19 pandemic in Norway did not affect the number of patients or mortality of patients with severe traumatic brain injury.**

INTRODUCTION

The World Health Organization (WHO) declared a pandemic due to the coronavirus disease of 2019 (COVID-19) on March 11, 2020.[1] The COVID-19 pandemic had enormous consequences on health care systems around the world.[2] To prevent a major outbreak of COVID-19 in their country and to reduce the risk of overwhelming the Norwegian health care system, the government of Norway announced several containment measures on March 12, 2020 with a strict lockdown until the end of April 2020, leading to a substantial reduction in treatment of injury in Norway.[3] Schools, universities, kindergartens, shops, and services considered nonessential were shut down. The guidelines for the general public included hand hygiene, keeping a distance of at least 2 m in public spaces, working from home whenever possible, and avoiding public transport. There were concerns that the lockdown and containment measures may have caused negative consequences for public health and mortality of conditions other than COVID-19.[4,5]

Traumatic brain injury (TBI) can be a severe condition and is one of the leading causes of trauma-related morbidity and mortality worldwide with considerable economic and social impact for affected individuals, their families, and society.[6] The management of TBI has been identified as one of the main priority areas in trauma research.[7] Efficient and timely prehospital and

Key words
- COVID-19
- Lockdown
- Traumatic brain injury

Abbreviations and Acronyms
AIS: Abbreviated Injury Scale
COVID-19: Coronavirus disease of 2019
GCS: Glasgow Coma Scale
IQR: Interquartile range
ISS: Injury Severity Score
TBI: Traumatic brain injury

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in-hospital treatment of severe TBI is imperative to reduce morbidity and mortality of this condition.[8] A recent review, based on smaller, mainly single-center studies, reported a significant change in the number of people acquiring TBI and mechanisms of injury during the pandemic.[9] The effect of containment and lockdown measures during the COVID-19 pandemic on the epidemiology and mortality rates of severe TBI on a national, population-based level is unknown.

The aim of this study was to evaluate the impact of the COVID-19 pandemic on admissions, mortality rates, and discharge destinations of trauma patients with severe TBI based on nationwide data from the National Trauma Registry of Norway.

MATERIAL AND METHODS

Ethics

This research project was approved by the Regional Committee for Medical and Health Research Ethics of Western Norway (REC-ID 143902) and Scientific Council and the patient representative of the National Trauma Registry of Norway. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were adhered to.[10]

Study Design and Period

The research design is a nationwide, observational cohort study based on prospectively collected data from the national trauma registry. The study period includes all patients with severe TBI included in the National Trauma Registry of Norway between January 1, 2017 and December 31, 2020. The study cohort was derived from the pandemic period (March 12 to December 31, 2020) and the control cohort from the corresponding prepandemic period from the years 2017 to 2019, for a 3:1 match between cohorts. Further analysis was performed for the lockdown period, defined as the time period between March 12 and April 30, 2020, and compared with the corresponding period of the years 2017 to 2019.

Data Source

Data for this study were retrieved from the National Trauma Registry of Norway, which is a comprehensive national database that aims to monitor the quality of trauma treatment and to facilitate continuous improvement of the trauma care chain in Norway. Norway is a country in Northern Europe with a population of approximately 5.3 million people in 2020, a median age of 39.8 years, and a life expectancy of 82.9 years. The national trauma registry covers the entire Norwegian population for a nationwide, publicly funded, single-payer health care system. All Norwegian hospitals ($n = 38$) admitting trauma patients with severe injury or suspected severe injury are routinely delivering data to the trauma registry, ensuring nationwide individual coverage of >95% and about 98% data completeness of key variables.[11] The core dataset of the trauma registry is based on the Utstein template for uniform reporting of data following major trauma.[12]

Study Population

All patients with severe TBI during the observation periods were identified from the National Trauma Registry of Norway. TBI is usually categorized into minimal, mild, moderate, and severe according to the Head Injury Severity Scale.[13] Severe TBI is usually defined as Glasgow Coma Scale (GCS) score between 3 and 8.[14] To include only patients with severe TBI from the database and to exclude patients with a GCS score ≤ 9 due to other causes (i.e., intoxication, medical cause, etc.), the patients for this research study were identified by the following variables: GCS score between 3 and 8, Abbreviated Injury Scale (AIS) severity score for head injuries of 3 or more, and Injury Severity Score (ISS) of 13 or more.[14-16]

Outcome Measures

The outcome measures of this study were 30-day mortality rates, in-house mortality rates, and discharge destination after acute care for the pandemic period in 2020 compared with the same time periods in the 3 years before. The 30-day mortality rate was defined as mortality rate at 30 days after injury as registered in the registry, in-hospital mortality rate was defined as mortality rate at definite care hospital, and discharge destination was registered after discharge from acute treatment at the definite care hospital (home; rehabilitation institution; other intensive or intermediate care ward; other hospital ward; other). Further analysis for 30-day mortality was performed for the lockdown period in March and April 2020.

Statistical Analysis

All statistical analyses were performed with SPSS version 26.0 (IBM, Armonk, New York, USA). Medians, percentages, and interquartile range (IQR) were used to describe the entire patient cohort, as well as the pandemic and prepandemic cohorts. The chi-square test was used for categorical variables. The independent samples median test was used for continuous variables.

Binary logistic regression analysis was performed to assess the impact of different variables on the 30-day and in-hospital mortality (dependent variables) of severe TBI. The regression models contained 4 different variables (age, gender, prepandemic/pandemic time period, AIS head injury severity). Statistical significance was defined as $P < 0.050$.

RESULTS

A total of 522 trauma patients with severe TBI were identified from the Norwegian Trauma Registry, 387 of whom (74.1%) were in the prepandemic time period and 135 (25.9%) in the pandemic time period. Data completeness for all included patients in this study was tested (98.7% for patient age; 99.7% for type, mechanism, and intention of injury; and 100% for gender, as well as 99.7% for all outcome variables).

Patient and injury characteristics did not differ significantly between the pandemic and prepandemic cohorts (**Table 1**). Median patient age was 53 years, and 73% of the patients were male. There were no significant differences in injury severity scores such as ISS, New Injury Severity Score, or distribution of maximum AIS scores for head injuries (**Table 2**). Length of stay increased significantly during the pandemic period (4 days, IQR 2–14 days, vs. 3 days, IQR 1–9 days; $P = 0.014$).

Outcome data are presented in **Table 3**. The 30-day mortality rate was 39% ($n = 201$) for all included patients, and 149 patients (39%) died in the prepandemic period versus 52 patients (38%) in the pandemic period ($P = 0.998$). Overall in-hospital mortality at

Table 1. Patient and Injury Characteristics of Severe Traumatic Brain Injury

Variables	All Patients	Prepandemic	Pandemic	*P* Value
Number of patients	522	387	135	
Age in years, median (IQR)	53 (30–71)	52 (30.5–70.5)	55 (29–71)	0.264
Gender, number (%)				
Male	379 (73%)	278 (72%)	101 (75%)	0.504
Female	1143 (27%)	109 (28%)	34 (25%)	
Dominating type of injury, number (%)				
Blunt	512 (98%)	377 (98%)	135 (100%)	0.091
Penetrating	8 (2%)	8 (2%)	0	
Mechanism of injury, number (%)				
RTA	177 (34%)	125 (33%)	52 (39%)	0.188
Hit by blunt object	41 (8%)	33 (9%)	8 (6%)	0.332
Low-energy fall	116 (22%)	84 (22%)	32 (24%)	0.718
High-energy fall	161 (31%)	125 (33%)	36 (27%)	0.222
Other	25 (5%)	20 (4%)	7 (4%)	0.998
Intention of injury, number (%)				
Unintentional	451 (87%)	332 (86%)	119 (88%)	0.493
Self-inflicted	38 (7%)	31 (8%)	7 (5%)	0.277
Other	28 (6%)	22 (6%)	9 (7%)	0.680
GCS at scene, median (IQR)	4 (3–6)	4 (3–6)	4 (3–6)	0.643
GCS in ED, median (IQR)	5 (3–8)	5 (3–8)	5 (3–8)	0.190

IQR, interquartile range; RTA, road traffic accident; GCS, Glasgow Coma Scale; ED, emergency department.

definite care hospital was 33% (n = 172), and 128 patients (33%) died in the prepandemic period versus 44 (33%) in the pandemic period (P = 0.920). Admission rates and 30-day mortality for the years 2017–2020 are presented in Figure 1. There were no statistically significant differences in discharge destination besides the number of patients discharged to home in the pandemic period (P = 0.003). During the strict lockdown period in March and April 2020, a total of 20 trauma patients (25%) with severe TBI were admitted compared with 61 patients (75%) in the corresponding periods of the 3 years before. The 30-day mortality during the lockdown period was 30% (n = 6) compared with 33% (n = 20) in the corresponding periods (P = 0.802).

The logistic regression model containing all variables was statistically significant (P > 0.001). Results are presented in Table 4. When adjusted for clinical relevant factors such as age, gender, and head injury severity, the mortality outcomes did not change during the pandemic period (see Table 4).

Table 2. Injury Severity and Length of Treatment

Variables	All Patients	Prepandemic	Pandemic	*P* Value
Number of patients	522	387	135	
ISS, median (IQR)	26 (24–34)	26 (25–35)	26 (24–33)	0.634
NISS, median (IQR)	43 (29–52)	42 (29–54)	41 (27–51)	0.220
AIS head injury severity, number (%)				
Serious	94 (18%)	68 (18%)	26 (19%)	0.603
Severe	115 (22%)	85 (22%)	30 (22%)	0.887
Critical	308 (59%)	232 (60%)	76 (56%)	0.590
LoS, median (IQR)	3 (1–9)	3 (1–9)	4 (2–13)	*0.014*
LoVT, median (IQR)	3 (1–10)	3 (1–11)	3 (2–9)	0.903

Italic values describe statistically significant values.
ISS, Injury Severity Score; IQR, interquartile range; NISS, New Injury Severity Score; AIS, Abbreviated Injury Score; LoS, length-of-hospital stay; LoVT, length of ventilator treatment.

DISCUSSION

On the basis of prospectively collected, nationwide data from the National Trauma Registry of Norway, the containment and lockdown measures during the COVID-19 pandemic affected neither the number of admitted patients nor the mortality of trauma patients with severe TBI in Norway. Thus one can assume that the quality of care for this severe traumatic condition was not significantly influenced by the COVID-19 pandemic. Despite reports on the impact of health care restrictions on the treatment of TBI in other regions and countries, the number of trauma patients admitted with severe TBI remained unchanged under containment and lockdown measures in Norway.[9,17,18] This is surprising, as one would have expected a reduction of patients during containment measures that included social distancing and aimed to reduce

Table 3. Outcome Variables of Severe Traumatic Brain Injury

Variables	All Patients	Prepandemic	Pandemic	*P* Value
30-Day mortality, number (%)	201 (39%)	149 (39%)	52 (38%)	0.998
In-hospital mortality, number (%)	172 (33%)	128 (33%)	44 (33%)	0.920
Discharge destination, number (%)				
Home	54 (10%)	31 (8%)	23 (17%)	0.003
Rehabilitation	105 (20%)	81 (21%)	24 (18%)	0.431
Other ICU	115 (23%)	91 (24%)	24 (18%)	0.165
Another hospital ward	36 (7%)	28 (7%)	8 (6%)	0.603
Other	40 (8%)	29 (7%)	11 (8%)	0.806

ICU, intensive care unit.

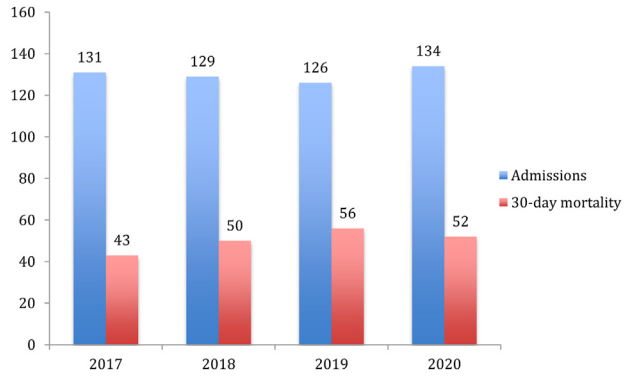

Figure 1. Admissions and 30-day mortality numbers of severe traumatic brain injury in Norway for the years 2017–2020.

traffic, sports, and social activities. Even the strict lockdown period in Norway did not result in fewer patients suffering from severe TBI, whereas others have reported up to 36% decrease in patients with TBI attending emergency departments during lockdown.[19] A recent systematic review including 13 studies on the epidemiology of TBI during the pandemic concluded that the mortality of TBI had increased in low-to middle-income countries during the pandemic but remained unchanged in high-income countries.[20] However, the review was based on 12 single-center studies and 1 multicenter study, whereas our study is the first one presenting national data.

In this study there were no differences in patient characteristics; both cohorts had the same median age and gender distribution. We also found similar median scores for ISS, New Injury Severity Score, and a similar distribution of maximum AIS scores for head injury severity, meaning that both cohorts were comparable. On the basis of the study results, there was also no significant change in injury patterns for patients with severe TBI observed during the pandemic period compared with earlier years. Surprisingly, the number of patients suffering severe TBI due to road traffic accidents in Norway remained unchanged despite a reported reduction of road traffic levels after the advice of staying and working at home.[9] The length of hospital stay for acute care of severe TBI increased significantly during the pandemic period. A recent study reported longer hospital stay of COVID-19–positive TBI patients; this may be the reason for the longer hospital stay in our cohort.[21] Unfortunately, data on the patients' COVID-19 status were not available from the trauma registry. Also, the restricted access to rehabilitation during the pandemic may have led to prolonged length of stay in that period.

More important, the restrictions due to the pandemic did not result in a higher mortality of severe TBI, indicating that the Norwegian health care system managed to deliver an equal treatment for this patient group despite the challenges that the pandemic may have caused for prehospital and in-hospital care of patients with this severe condition. Restrictions in access to health care have been reported for patients with other traumatic conditions in Norway.[3] There has also been reported restricted access to intensive care for other severe conditions due to an overload of COVID-19 patients in need of ventilator or intensive care treatment.[22] However, these facts obviously did not influence the mortality rates of severe TBI during the pandemic in Norway. A study from Finland, with the similarities in population numbers and health care system, showed similar results for intensive care admissions of patients with TBI.[23]

A change in discharge destination was observed with a larger number of severe TBI patients discharged directly to home care during the pandemic period. But on a positive note, this study did not suggest a decrease in use of rehabilitation care such as others have reported for patients in need of neurorehabilitation.[24,25] The effect of direct discharge to home care, which was observed during the pandemic period, possibly leading to poorer long-term functional outcome, should warrant further investigation.

Table 4. Results from Binary Logistic Regression Analysis with 30-Day Mortality and In-Hospital Mortality as Dependent Variables

Variables	*P* Value	OR	95% CI for OR
30-Day mortality			
Age	>0.001	1.03	1.02–1.04
Gender	0.028	1.64	1.05–2.55
Prepandemic/pandemic time period	0.859	0.96	0.61–1.52
AIS head injury severity	>0.001	3.91	2.54–6.02
In-hospital mortality			
Age	>0.001	1.03	1.02–1.03
Gender	0.124	1.41	0.91–2.20
Prepandemic/pandemic period	0.755	0.93	0.58–1.48
AIS head injury severity	>0.001	4.08	2.60–6.41

OR, odds ratio; CI, confidence Interval; AIS, Abbreviated Injury Score.

Strengths and Limitations

The study strengths include the use of prospectively collected data from a nationwide registry and high data completeness representing a high internal validity of the data. One limitation of this study is the lack of long-term outcome data, per design of the trauma registry as many TBI patients may improve over a longer time period. Many countries had different containment strategies during the pandemic, and the results of this study based on Norwegian data cannot be generalized and applied to other countries.

CONCLUSIONS

The containment and lockdown measures during the COVID-19 pandemic in Norway did not affect the number of admitted patients or the mortality of trauma patients with severe TBI. A larger proportion of patients were discharged to home care during the pandemic, but the number of patients discharged to specialized rehabilitation remained unchanged.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Clemens Weber: Conceptualization, Methodology, Formal analysis, Writing — original draft, Project administration. **David Werner:** Writing — review & editing. **Kenneth Thorsen:** Writing — review & editing. **Kjetil Søreide:** Methodology, Writing — review & editing, Supervision.

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