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Increasing incidence of ED-visits and admissions due to traumatic brain injury among elderly patients in the Netherlands, 2011–2020

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ABSTRACT

Background and importance: Traumatic brain injury (TBI) is a leading cause of disability and mortality worldwide. Nowadays the highest combined incidence of TBI-related emergency department (ED) visits, hospitalizations and deaths occurs in older adults. Knowledge of the changing patterns of epidemiology is essential to identify targets to enhance prevention and management of TBI.
Objective: To examine time trends of ED visits, admissions, and mortality for TBI comparing non-elderly and elderly people (aged ≥ 65 years) in the Netherlands from 2011 to 2020.
Design: We conducted a retrospective observational, longitudinal study of TBI using data from the Dutch Injury Surveillance System (DISS) and Statistics Netherlands from 2011 to 2020.
Outcome measure and analysis: The main outcome measures were TBI-related ED visits, hospitalizations, and mortality. Temporal trends in population-based incidence rates were evaluated using Poisson regression. We compared patients under 65 years and patients aged 65 years or older.
Main results: From 2011 to 2020, absolute numbers of TBI related ED visits increased by 244%, and hospital admissions and mortality showed an almost twofold increase in patients aged 65 years and older. The incidence of TBI-related ED visits and hospital admission increased also in elderly adults, with 156% and 51% respectively, whereas the mortality remained stable. In contrast, overall rates of ED visits, admissions, and mortality, and causes for TBI did not change in patients younger than 65 years during the study period.
Conclusion: This trend analysis shows a significant increase of ED-visits and hospital admission for TBI in elderly adults from 2011 to 2020, whereas the mortality remained stable. This increase cannot be explained by the aging of the Dutch population alone, but might be related to comorbidities, causes of injury, and referral policy. These findings strengthen the development of strategies to prevent TBI and improve the organization of acute care necessary to reduce the impact and burden of TBI in elderly adults and on healthcare and society.

Introduction

Traumatic brain injury (TBI) is defined as an alteration of brain function or other evidence of brain pathology, caused by an external force to the head [1]. It is a common neurological condition and a leading cause of morbidity, disability, and mortality worldwide [2,3]. Each year approximately 2.8 million patients in the United States (US) and 2.5 million in the European Union (EU) sustain a TBI [4]. It not only causes health loss and disability for individuals, but also represent an economic burden to health-care systems through lost productivity and high health-care costs [2].

The epidemiology and underlying causes of TBI are changing. Nowadays, patients with TBI in high-income countries are characterized by an older age, with falls as the primary mechanism of injury [2,3,5]. The highest combined incidence of TBI-related emergency department (ED) visits, hospitalizations, and deaths in fact occur in older adults [6,

Abbreviations: ED, Emergency department.

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7]. By 2050, the number of elderly adults will have risen worldwide to 2.1 billion [8].

Official statistics report large variations in ED visits, hospital admissions and mortality rates for TBI across the EU, likely due to differences in data collection, case ascertainment, and case definition [5,9]. Between 1998 and 2012, there were approximately 500 000 TBI-related ED visits, 222 000 TBI-related admissions and 17 000 TBI-related deaths in the Netherlands [10]. In the same period, the figures for persons aged 65 years and older comprised 81 000 TBI-related ED visits, 53 000 TBI-related admissions and 8000 TBI-related deaths. The exact epidemiology and patterns of geriatric TBI for the Netherlands and many other European countries in the last decade is unknown. Timely epidemiologic studies are needed to estimate the trends in ED visits, admission numbers and mortality of patients over time at global, regional, and national levels to guide evidence-based health-care policy for improved prevention and management of TBI and to provide a projection for the future. Therefore, this study aims to evaluate time trends of ED visits, admissions, and mortality for traumatic brain injury comparing non-elderly and elderly people (aged $\geq$ 65 years) in the Netherlands from 2011 to 2020.

Methods

Data sources

In this observational longitudinal study, we included all patients with ED visits, hospital admissions or mortality because of TBI in the period 2011–2020 using two Dutch registration systems, namely the Dutch Injury Surveillance System (DISS) (Letsel Informatie Systeem; LIS) and the Office for National Statistics, Statistics Netherlands (Centraal Bureau voor de Statistiek; CBS), respectively.

We extracted data on ED visits and hospital admissions from the DISS database which is an ongoing monitoring system of the Dutch Consumer Safety Institute (VeiligheidNL). Information is registered from all patients who attend the ED for an injury. DISS is based on a selection of fourteen geographically distributed Dutch hospitals that provide a 24-hour medical emergency service, forming a representative sample of hospitals in the Netherlands. The DISS data set represents 16% of all EDs in the Netherlands and includes general and academic hospitals. Therefore, data collected in the DISS hospitals can be extrapolated to national estimates. For extrapolation of the sample, the number of trauma-related ED treatments in DISS hospitals is multiplied by a factor derived from the quotient of all trauma-related hospital admissions in the Netherlands divided by trauma-related hospital admissions in DISS hospitals [11].

The cause of death statistic by the Office for National Statistics, Statistics Netherlands (CBS) [12] is a registration based on causes of death (ICD-10) from all deceased individuals registered in the Netherlands. The information is based on the compulsory notification of cause of death by the physician treating the deceased at the time of death or by a pathologist. For every deceased, a cause of death certificate is completed, which is used exclusively for statistical purposes, and is sent to CBS. The reliability of registration of causes of death is generally good [13].

Study population

We included all patients who attended the ED for TBI, were admitted to the hospital (which was linked with the DISS database) for TBI or died because of TBI between 1 January 2011 and 31 December 2020. Elderly adults were defined as having an age of 65 years or older. In the DISS database, injuries in the ED are coded according to a classification of the type of injury and the location of the body, based on the International Classification of Diseases (ICD-10-CM) [14]. TBI is defined in the DISS registration as having a concussion (ICD10-CM code S06.0) or other skull-brain injury (S02.0-1, S02.7, S02.9, S06.1-9, S04.0-9, S07.1-9, T02.0, T04.0).

Statistical analysis

We expressed absolute numbers and the estimated annual incidence of ED visits, hospital admissions and mortality rates for TBI per 100 000 population for the equivalent Office for National Statistics, Statistics Netherlands, population estimate for that year. ED visits were specified for age and sex for each year. Hospital admissions, deaths, and trauma mechanisms only for age. Because of a certain measure of uncertainty, numbers are rounded to thousands in this manuscript. We defined the following age groups: 0–64 years and $\geq$65 years. Poisson regression was used to estimate the rate ratio (multiplicative increase of the rate per year over the study period) and 95% confidence intervals. Rate ratios for the overall study period (2011–2020) were estimated with a rate ratio of 1.0 implying no annual change in rate, and a 95% confidence interval that includes 1.0 indicating that the observed rate ratio is not statistically significant. All statistical analyses were performed using IBM Statistical Package for Social Sciences (SPSS) version 27.

Results

During the study period from 2011 through 2020 approximately 6 984 000 ED visits, 1 427 000 hospital admissions and 81 000 deaths due to trauma were registered. Of these, 518 000 ED visits (7.4% of total), 238 000 hospital admissions (16.7% of total), and 14 000 deaths (17.3% of total) were a consequence of TBI (Table 1). Elderly adults accounted for 34%, 35%, and 64% of these TBI numbers. The population increased in this period from 16.7 million in 2011 to 17.4 million (4% increase) in 2020 in the Netherlands. In the same period, the population aged $\geq$65 years increased from 2.6 million in 2011 to 3.4 million (31% increase) in 2020.

Incidence rates

We present an overview of the absolute numbers of TBI-related ED-visits, hospital admissions and mortality by age group in Table 1. Figs. 1 and 2 show the changes in incidence rates of TBI- related ED-visits (2a), hospital admissions (2b) and mortality (2c) in non-elderly and elderly people between 2011 and 2020.

ED visits

From 2011 until 2020, the absolute number of ED visits among patients aged 65 years and older increased by 244%; from 9 200 in 2011 to 31 000 in 2020. Besides this absolute increase, the incidence rates increased from 357 in 2011 to 910 ED visits per 100 000 population per year in 2020 (156% increase; IRR 2.556; 95% CI 2.261–2.889). The absolute number of ED visits due to TBI in adults under 65 years of age increased far less, from 33 000 in 2011 to 37 000 in 2020 (increase 12%). In addition, there was a nonsignificant overall change in the incidence rates of TBI related ED visits, from 236 in 2011 to 264 ED visits per 100 000 population per year in 2020 (12% increase; IRR 1.119; 95% CI 1.039–1.333). The changes in incidence rates of TBI-related ED visits in men and women per age group are shown in Table 2.

Hospital admissions

The absolute number of TBI-related hospital admissions almost doubled among patients aged 65 years and older, from 6 000 in 2011 to 11 000 in 2020. In line with the increase in absolute numbers, the incidence rates increased from 222 to 334 hospital admissions per 100 000 population per year (51% increase; IRR 1.505, 95% CI 1.270–1.783). In contrast to patients aged 65 years or older, absolute numbers of TBI-related hospital admissions decreased by 6.7%, from 15 000 in 2011 to 14 000 in 2020. The incidence rates showed a

Table 1
Key figures on traumatic brain injury between 2011 and 2020 in the Netherlands: emergency department visits, hospital admissions, and mortality.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
ED visits TBI< 65 (total)	33 000	34 000	30 000	30 000	33 000	35 000	33 000	37 000	39 000	37 000
ED visits TBI 65+ (total)	9 000	10 000	10 000	11 000	16 000	18 000	19 000	24 000	29 000	31 000
Admissions TBI <65 (total)	15 000	17 000	16 000	14 000	16 000	15 000	14 000	20 000	15 000	14 000
Admissions TBI 65+ (total)	6 000	6 000	6 000	6 000	9 000	9 000	9 000	9 000	11 000	11 000
Mortality TBI <65 (total)	500	500	500	400	500	500	500	400	400	500
Mortality TBI 65+ (total)	700	800	800	900	1 000	1 000	1 000	1 000	1 000	1 000
Population (total)	16 656 000	16 730 000	16 780 000	16 829 000	16 901 000	16 979 000	17 082 000	17 181 000	17 282 000	17 408 000
Population <65	14 061 000	14 014 000	13 955 200	13 910 000	13 893 000	13 893 000	13 922 000	13 942 000	13 968 000	14 015 000
Population 65+	2 595 000	2 716 000	2 824 000	2 919 000	3 008 000	3 085 000	3 160 000	3 239 000	3 314 000	3 393 000
ED visits TBI 65+/ ED TBI (total) (%)	22	23	25	27	32	35	36	39	43	46
Admissions TBI 65+/Admissions TBI (total) (%)	27	26	29	30	35	39	38	32	42	45
Mortality TBI 65+/ Mortality TBI (total) (%)	59	63	63	68	67	71	72	76	75	75

ED=emergency department, TBI=traumatic brain injury.

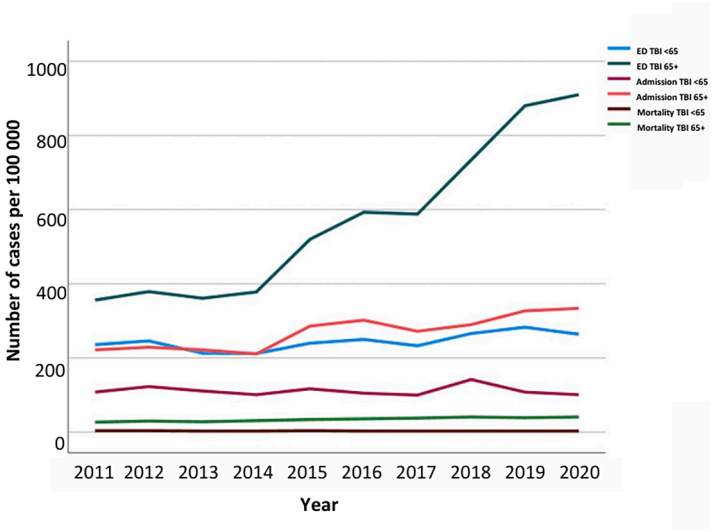

Fig. 1. Time trends in ED-visits, hospital admissions and mortality per 100 000 population from 2011 to 2020 in patients younger and over 65 years of age. ED=emergency department, TBI=traumatic brain injury.

comparable decrease from 108 in 2011 to 101 admissions per 100 000 population per year in 2020 (7% decrease; IRR 0.935; 95% CI 0.713–1.227).

Mortality

The mortality rate for TBI increased with 43% in patients aged 65 years and older, from 700 in 2011 to 1000 in 2020. The incidence rates showed a nonsignificant increase in mortality due to TBI, from 27 to 41 deaths per 100 000 population per year (52% increase; IRR 1.519; 95% CI 0.934–2.468). In patients younger than 65 years of age, the mortality rate remained stable with 500 deaths in both 2011 and 2020. Incidence rates for mortality did not change significantly, from 4 to 3 per 100 000 population deaths per year (25% decrease; IRR 0.750; 95% CI 0.168–3.351).

Trauma mechanisms

Table 3 shows the trauma mechanisms causing TBI in patients equal or older than 65 years and younger than 65 years in 2011 compared to 2020. Throughout the study period, falls and road traffic accidents (RTA) were the main cause for TBI in patients younger than 65 years of age (128 000 and 113 000 ED visits; 35% and 33%) and falls in patients aged 65 years and older (127 000 ED visits; 64%).

Over time, the overall incidence rates of TBI related to falls, RTA, and other causes (e.g. entrapment, self-mutilation, bumping head against object) increased significantly as cause for TBI, from 233 to 676 per 100 000 population per year (190% increase; IRR 2.901 95% CI 2.500–3.367) for falls, from 81 to 157 per 100 000 population per year (96% increase; IRR 1.938; 95% CI 1.482–2.534) for RTA, and from 34 to 59 per 100 000 population per year (79% increase; IRR 1.788; 95% CI 1.168–2.738) for other causes. In contrast, we observed no trends for trauma mechanisms for TBI in patients younger than 65 years since 2011 (Table 3).

Discussion

We found that among patients aged 65 years or older in the Netherlands, absolute numbers of TBI related ED visits increased by 244%, with an almost twofold increase of hospital admissions and mortality between 2011 and 2020. In addition, incidence rates of TBI-related ED visits and hospital admissions have consistently increased since 2011 in this category, indicating that the rise in the number of elderly adults treated and admitted in hospitals cannot be explained by aging and changing population structure alone, but might be related to comorbidities, causes of injury, and referral policy.

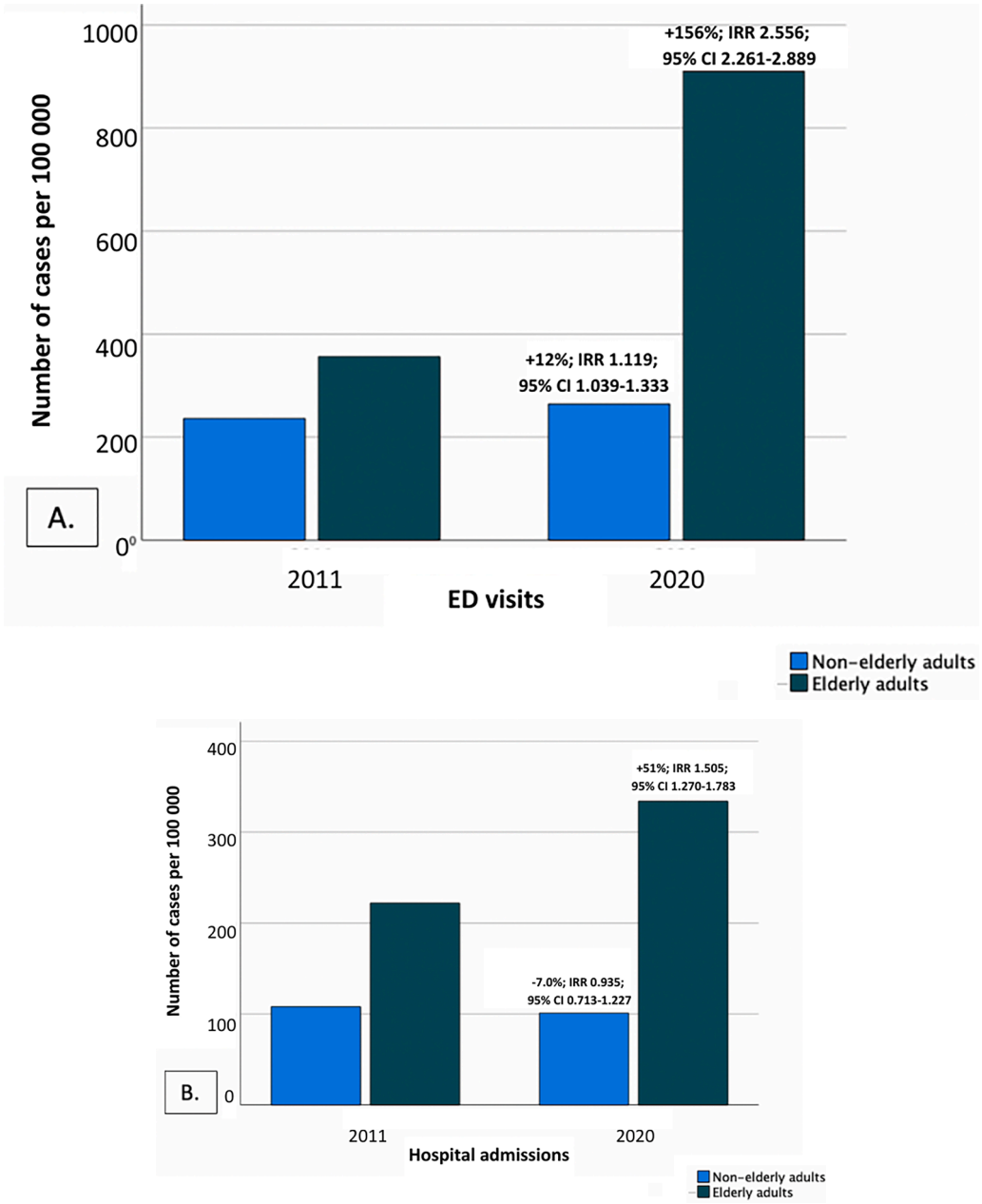

Fig. 2. Incidence proportions on a logarithmic scale of TBI ED visits (A), admissions (B), and mortality (C) in the Netherlands per 100 000 population, 2011 and 2020 compared. ED=emergency department, TBI=traumatic brain injury.

In the current study we observed that between 2011–2020 the ED-visits and hospital admissions due to TBI in patients aged 65 years or older kept increasing, although this was less steep than in the period 1998–2012 [10] with an increase in ED visits of 237%, compared to 199% between 2011 – 2020. For hospital admissions the increase was from 156% to 51% from 2011–2020. In contrast, the incidence of TBI-related ED-visits and hospital admissions in patients younger than 65 years of age remained stable during the study period.

A recent systematic review on the epidemiology of TBI in Europe showed that mean incidence rates remained broadly the same across studies of all ages [9]. However, longitudinal studies in several European countries and the United States during the same period observed that the overall incidence of ED-visits and hospital admissions in elderly adults increased [6,15–19]. Nevertheless, no recent comprehensive description of the trends in the elderly population for a decade or longer in Europe is available.

The question is whether these absolute numbers reflect only the increase of elderly in the overall population. During the study period, the overall population aged 65 years and older increased by 31%. The ED visits and hospital admission-based incidence rates in this age group increased with 156% and 51% respectively. As such, this increase cannot be explained by the aging of the Dutch population alone. The increment in ED visits of older adults with TBI might have several causes. First, elderly adults are more mobile compared to the past due to improved health care services and the development of mobility aids [20]. As a result of a more active and mobile lifestyle, elderly adults are supposed to be at higher risk for falling or a RTA with a TBI as a consequence. Second, as people age, the number of patients living with various medical conditions will increase [21]. The presence of pre-existing health conditions is a known risk factor for sustaining a TBI [22].

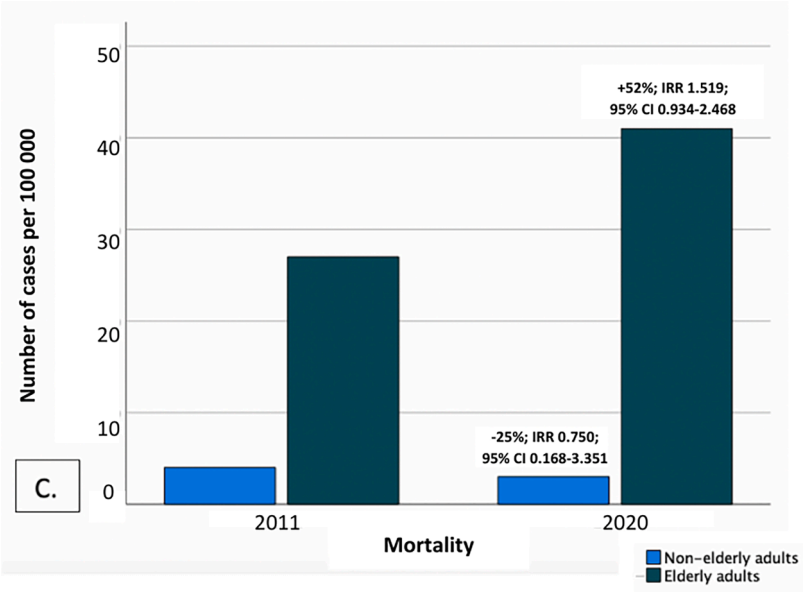

Fig. 2. (*continued*).

Table 2
Characteristics of ED-visits for TBI in men and woman between 2011 and 2020.

Age-group	Incidence		Rate per 100 000 people		IRR (95% CI)	p-value
	2011	*2020*	*2011*	*2020*		
Men <65 y	20 000	21 000	283	302	1.067 (0.907–1.255)	0.432
Woman <65 y	13 000	16 000	188	225	1.197 (1.023–1.502)	0.069
Men ≥ 65 y	4 000	14 000	357	880	2.629 (2.327–2.970)	<0.001
Woman ≥ 65 y	5 000	17 000	356	936	2.465 (2.180–2.788)	<0.001

CI=confidence interval, IRR=incidence rate ratio, TBI=traumatic brain injury, *y*=years.

Table 3
Causes of injury in non-elderly and elderly adult presenting with TBI in the ED covering the period from 2011–2020.

Trauma mechanism	**Incidence**		**Rate per 100 000 people**		**IRR (95% CI)**	**p-value**
	2011	***2020***	***2011***	***2020***		
Patients < 65 y						
Fall	12 000	16 000	88	112	1.271 (0.963–1.683)	0.104
RTA	10 000	11 000	74	78	1.054 (0.767–1.449)	0.152
Work	1 000	2 000	9	11	1.222 (0.506–2.949)	0.655
Sports	3 000	3 000	18	21	1.167 (0.622–2.190)	0.631
Violence	3 000	2 000	21	15	0.714 (0.368–1.386)	0.320
Other	4 000	4 000	26	27	1.038 (0.606–1.779)	0.891
Patients ≥ 65 y						
Fall	6 000	23 000	233	676	2.901 (2.500–3.367)	<0.001
RTA	2 000	5 000	81	157	1.938 (1.482–2.534	<0.001
Work	20	200	1	5	5.00 (0.584–42.797)	0.142
Sports	100	300	4	9	2.250 (0.693–7.306)	0.177
Violence	134	142	5	4	0.800 (0.215–2.979)	0.739
Other	1 000	2 000	34	59	1.788 (1.168–2.738)	0.008

ED=emergency department, CI=confidence interval, IRR=incidence rate ratio, TBI=traumatic brain injury, RTA=road traffic accident, *y*=years.

Furthermore, elderly adults are more likely to use antithrombotic medication which can increase the risk and severity of intracranial hemorrhage after sustaining a TBI. Accordingly, elderly adults with comorbidities and use of antithrombotics are more often referred to the ED for a head CT or treatment of co-occurring injuries [22,23]. In addition, the introduction and increased use of direct oral anticoagulants (DOACs) since 2009 [24], especially in elderly people, may have contributed to increased ED referrals en hospital admission. Despite their potential benefits, including a rapid onset, fixed dosing an no need for monitoring, the prescription of DOACs was initially challenged, due to lack of reversal agents, unknown bleeding risk, uncertainty about the risk of hematoma progression and lack of guidance on how to manage TBI patients using a DOAC. These insecurities might have lowered the threshold for ED referral and hospital admission of DOAC–treated patients after TBI. Third, changes in the head injury guideline of the Dutch College of General Practitioners in 2015 might have resulted in an increased awareness among primary care professionals of the risk of traumatic intracranial lesions in the elderly after TBI and, consequently, in increased referral practices. More defensive medicine and lower thresholds for diagnostic imaging might be other possible causes. The observation that the number of ED visits increased much more than the hospital admissions could support this theory.

Regarding the increase in hospital admissions, it is possible that the increased use of head CTs and improvement of the quality of CT scanners in the last decade might have led to better detection of traumatic lesions and, as a result, in an increase in hospital admissions [25]. Another explanation might be an increase of injury severity in elderly adults. The majority of TBIs sustained by elderly adults are nowadays attributed to falls [26]. Although it may seem counterintuitive, this apparently low-energetic injury mechanism may lead to a higher proportion of severe injuries (extra-axial hemorrhages or contusions) than traffic accidents, possibly because of more focal damage aggravated by antithrombotics [17,27]. Moreover, due to anatomic and physiologic

changes that accompany aging, older patients experience more severe consequences than younger people, even from seemingly mild injuries [28–31]. In addition, a recent nationwide cohort study in the Netherlands found that moderate and severe TBI was far more common in the elderly than in the overall study population, with falls as main cause of TBI in their elderly population as well [32]. Half of the elderly adults in this study had an injury severity score (ISS) over 16, indicating major trauma [33] and almost half of polytrauma patients were elderly adults. Therefore, one could imagine that these patients are more often admitted for further treatment.

Consistent with previous findings, in our study falls were the main cause of TBI in the elderly and fall related TBI incidence rates increased over time in this age group[23]. We also observed an increase in RTA as a cause for TBI in elderly adults. A clear explanation for this finding is not yet known although this rise might be due to an increase in bicycle-related TBI in elderly adults. It is possible that elderly adults do cycle more nowadays than they used to do in the past, because of the introduction of e-bikes [34–36]. Currently, elderly adults account for almost 45% of all bicycle-related ED visits in the Netherlands [37], and older cyclists have been identified as an important risk group for TBI as they represent highest ED attendance, injury severity, admission to hospital and intensive care unit, and economic costs [38–40]. Future research is necessary to gain a better insight in the observed trends in trauma mechanisms, to improve the approach for prevention of TBI in elderly adults in the Netherlands.

The trend of increasing TBI related ED visits and hospital admissions in elderly will have consequences for the workload on healthcare professionals, available hospital beds and health care expenses. The population of elderly people is expected to double by 2050 [8] and the increasing trends in ED-visits and hospital admissions are likely to continue as well. Related to this, healthcare consumption and healthcare costs are expected to show a rise in the coming decades on top. Therefore, policy makers need to consider the changing demands of TBI on health-care services and proactively improve the organization of acute care aiming to not overburden the already struggling post-COVID-19 healthcare systems.

A major strength of this study is this detailed nationwide overview of TBI in the Netherlands with high number of valid data that are compared to an earlier period and might provide information that is applicable on an international level. However, this study has some limitations as well. First, miscoding, and incomplete data are inherent to using nationwide or large registries such as the DISS and the Statistics Netherlands. Misclassification or incomplete recording of injuries is however a specific concern in adults aged 65 years or older. Injuries can be missed for various reasons; in multiple injured elderly adults, for example, the clinician might not register all injuries or only the main (often the most severe) diagnosis. In the case of death after a TBI by an elderly adult, clinicians may not recognize the precipitating injury as the actual cause of death and consider the underlying cause of death to be subsequent pathology (e.g., pneumonia), or attribute the cause of death to preexisting medical conditions (e.g., cardiovascular disease) rather than on more recent traumatic injuries [41,42] resulting in an underestimation of true numbers in this age group. Second, the DISS registry included only records on TBI presented at the ED and may not include all TBIs because some cases may be treated outside the hospital, not necessitating an ED presentation. This underestimates the true nationwide incidence of TBI. Third, we used different national registries for this study research. The DISS database only records data from Dutch emergency departments, and Statistics Netherlands records data from diseased patients. The different registries provide complementary useful data, but currently cannot be linked. Thus, to provide solid and complete data on for example the incidence rate, health care use, and outcome, one national registry which includes complete short- and long-term data on both admitted and non-admitted patients is needed. Fourth, the used databases do not contain information regarding underlying diagnoses, co-morbidities, medication use, injury severity, CT outcomes, and treatments. This hampers the interpretation of causal mechanisms behind the observed trends. Another limitation concerns the classification of TBI. TBI patients treated at the ED and admitted to the hospital were registered in the DISS as having a ‘‘Concussion’’ or ‘‘Other skull – brain injury’’ (including fractures and intracranial injury). Due to this undercoding, we could not provide detailed stratification of the TBI severity. Last, the results only relate to the Netherlands and therefore may not be translated to other countries. However, the trends we observed seem comparable to figures from European studies [15–19].

Conclusions

This trend analysis shows that ED-visits and hospital admission for TBI have significantly increased in elderly adults in the last decade from 2011 to 2020. This increase cannot be explained by the aging of the Dutch population alone, but might be related to comorbidities, causes of injury, and referral policy. Strengthening of strategies to prevent TBI as well as improving the organization of acute care is necessary to reduce the impact and burden of TBI in elderly adults and on healthcare and society.

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Declaration of Competing Interest

No competing financial interests exist.

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