CHAPTER 2

Traumatic brain injury in the Netherlands
Trends in emergency department visits, hospitalization and mortality between 1998 and 2012

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ABSTRACT

Background
Traumatic brain injury (TBI) is a major cause of morbidity and mortality worldwide. The effects of epidemiological changes such as ageing of the population and increased traffic safety on the incidence of TBI are unknown.

Objective
The objective of this study was to evaluate trends in TBI related emergency department (ED)-visits, hospitalization and mortality in the Netherlands between 1998 and 2012. Design This was a retrospective observational, longitudinal study.

Main outcome measures
The main outcome measures were TBI-related ED-visits, hospitalization and mortality.

Results
Between 1998 and 2012 there were 500,000 TBI related ED visits in the Netherlands. In the same period there were 222,000 TBI related admissions and 17,000 TBI related deaths. During this period there was a 75% increase in ED visits for TBI, a 95% increase for TBI related hospitalization; overall mortality due to TBI did not change significantly. Despite the overall increase in TBI related ED visits this increase was not evenly distributed among age groups or trauma mechanisms. In patients younger than 65 years, a declining trend in ED visits for TBI caused by road traffic accidents was seen. Among patients 65 years or older, ED visits for TBI caused by a fall increased markedly. TBI related mortality shifted from mainly young (67%) and middle-aged people (< 65 years) to mainly elderly (63%) individuals (≥65 years) between 1998 and 2012. The conclusions of this study did not change when adjusting for changes in age, gender and overall population growth.

Conclusions
The incidence of TBI-related ED visits and hospitalization increased markedly between 1998 and 2012 in the Netherlands. TBI-related mortality occurred at an older age. These observations are probably the result of a change in aetiology of TBI, specifically a decrease in traffic accidents and an increase in falls in the ageing population. This hypothesis is supported by our data. However, ageing of the population is not the only cause of the changes observed; the observed changes remained significant when correcting for age and sex. The higher incidence of TBI with a relative stable mortality rate highlights the importance of clinical decision rules to identify patients with a high risk of poor outcome after TBI.

Introduction

Traumatic brain injury (TBI) is a major cause of mortality and morbidity worldwide affecting ~ 10 million individuals annually.[1,2,3] Although several definitions of TBI exist, the most frequently used definition is 'an alteration in brain function, or other evidence of brain pathology, caused by an external force'.[1,4,5]

In the USA TBI accounts for ~2.5 million emergency department (ED) visits, hospitalizations and deaths annually; of these, ~ 53,000 individuals die as a result of TBI.[1] The exact incidence for the Netherlands and many other European countries is unknown.[5]

TBI used to be most prevalent in young men. However, in most industrialized countries, TBI is predominantly a disease of the elderly nowadays. [1,5] This presumed shift in the epidemiology of TBI in the last decades is most likely the result of two important changes that affect the incidence and epidemiology of TBI: first ageing of the population; increasing age is associated with an absolute increase of TBI. [6,7,8] In the Netherlands the percentage of the population aged 65 years or older was 12.8% in 1990, increased to 17.8% in 2015 and it is estimated to be 26.5% in 2040. [9,10] For other parts of the western world, similar trends are to be expected. Another important development is the decrease in traffic accidents. During the last decades, traffic safety increased and the number of traffic deaths in the Netherlands decreased substantially from 1149 in 1998 to 650 in 2012. [9] Subsequently, falls have surpassed traffic accidents as most important cause of TBI-related deaths. [9] The effects of this presumed shift from mainly young traffic accident victims to elderly fall victims on ED visits and hospitalizations in the Netherlands is unknown.

This study evaluates trends in epidemiology of TBI patients in the Netherlands between 1998 and 2012.

We hypothesize that the ageing population in the Netherlands is associated with an increased incidence of TBI despite a decrease of traffic accidents.

Methods

Data sources

In this observational, longitudinal study all patients with ED visits, hospitalization or mortality because of TBI in the period 1998-2012 were included using the Dutch Injury Surveillance System (Letsel Informatie Systeem; LIS), the National Medical Register (Landelijke Medische Registratie; LMR), and Statistics Netherlands (Centraal Bureau voor de Statistiek; CBS), respectively.

The cause-of-death statistic by CBS is a registration based on all 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 reasonable to good. [9,11]

The National Medical Register (LMR) has been set up by the hospitals in the Netherlands for the benefit of research and policy. The LMR contains data of admitted patients on demographics (age, sex), hospital, date of admission and injury diagnosis (ICD-9CM).

All general and academic hospitals have statutory obligations to participate in the LMR. Hence, using the LMR data approximates the true number of admissions throughout the Netherlands.[12] The reliability and completeness of LMR data are high.[13,14]

ED visits were extracted from the LIS database; participation in LIS is not compulsory. The LIS database is a continuous monitoring system in which next to demographics, injury diagnoses and injury mechanisms are registered. LIS is based on 13 geographically distributed EDs in The Netherlands, resulting in a representative 12-15% sample of injury-related ED visits that can be extrapolated to national estimates. For extrapolation of the sample, a factor was calculated in which the number of trauma-related ED treatments in LIS hospitals was multiplied by the quotient of all trauma related hospital admissions in the Netherlands divided by trauma related hospital admissions in LIS hospitals. [15,16] In addition, a data set was created to standardize (with 2012 as standard) for differences in distribution of sex and age. This data set was used to perform supplementa analysis. Because of a certain measure of uncertainty, numbers are rounded to thousands in this manuscript.

Inclusion

All patients who attended a Dutch ED for any trauma, were discharged from a Dutch hospital for any trauma or died because of any non-natural cause between 1 January 1998 and 31 December 2012 were included. The study groups comprise all patients who visited the ED for TBI, were admitted for TBI or died from TBI. TBI was defined using the ICD-9CM codes for LMR; the ICD-10 codes for CBS and the LIS codes for ED visits. All patients with intracranial injury and/or a fracture of the skull *(ICD9-CM codes 800-804 and 850–854; ICD10 codes S01.0; S02.0;S02.1; S02.3; S02.7-9; S04.0; S06; S07; S09.7-9; T90.1-2; T90.4-5; T90.8-9)* were included in this group, irrespective of age and sex. The study groups were compared with all ED patients with non-TBI trauma, all admitted patients with non-TBI-trauma or all deaths from non-natural causes other than TBI.

Data and statistical analysis

SPSS for windows (IBM SPSS Statistics, SPSS Inc, Chicago, Illinois, USA) was used for statistical analyses. The data set was subdivided into TBI patients and non-TBI patients, and was deliberately not standardized for age as the effects of ageing of the population on TBI epidemiology are one of the research questions of this study. Cumulative incidence is shown as number of new cases throughout the population of the Netherlands per year. Incidence proportions (per 100,000 per year) were calculated using Statistics Netherlands data [9]. A Poisson regression was used to determine the difference in the increase in incidence over time using a generalized linear model. As the Poisson distribution was used to describe this population, the same method was used to analyze the change in incidence proportions over time. To determine a significant change of cumulative incidence proportions between 1998 and 2012, MedCalc statistical software (version 16.4.3; MedCalc Software, Ostend, Belgium) was used to compare proportion using a c^2-test. Statistical significance was determined by a *P*-value of less than 0.001. The study was approved by the medical ethical review board (METC Zuidwest Holland, number 15-072).

Results

Incidence measures in total population

Between 1998 and 2012 there were ~13,651,000 trauma-related ED visits, of which 500,000 (3.7%) were because of TBI. The total number of hospital admissions for trauma during the study period was 1,958,000, of which 222,000 (11%) were for TBI. The total mortality due to non-natural causes was 86,000, of which 17,000 (20%) were caused by TBI (Table 1).

Between 1998 and 2012, according to the Poisson regression model without correction for age and sex, there was a significant increase in ED visits for TBI, from 153/100,000 in 1998 to 267/100,000 in 2012 (75% increase, $P < 0.001$); in hospital admissions for TBI from 64/100,000 per year to 125/100,000 per year (95% increase, $P < 0.001$); and a nonsignificant change in mortality because of TBI from 6.8/100,000 per year to 7.2/100,000 per year (6% increase, $P = 0.17$).

In comparison with other trauma, the ED visits increased significantly more for TBI ($P < 0.001$). According to the Poisson regression model, ED visits for TBI increased with 4.6% each year versus a decrease of 2.1% for ED visits for other injury types. There was a significant increase ($P < 0.001$) in admissions for TBI (5.5% increase per year) compared with admissions for other injury (3.3% increase per year). The TBI related mortality did not change compared with overall mortality by non-natural causes (TBI related mortality increased 0.8% per year, mortality by other non-natural causes increased 0.9% per year, $P = 0.78$)

Comparing TBI-related admissions with TBI-related ED visits and mortality, the increase in TBI-related hospital admissions (5.5% per year) increased significantly ($P < 0.001$) more than the TBI related ED visits (4.6% per year). Moreover, TBI-related mortality increased significantly less than TBI-related admissions (0.8% vs. 5.5% per year) ($P < 0.001$). The changes in the crude incidence of TBI in the Netherlands between 1998 and. 2012 are shown in Figures 1 and 2.

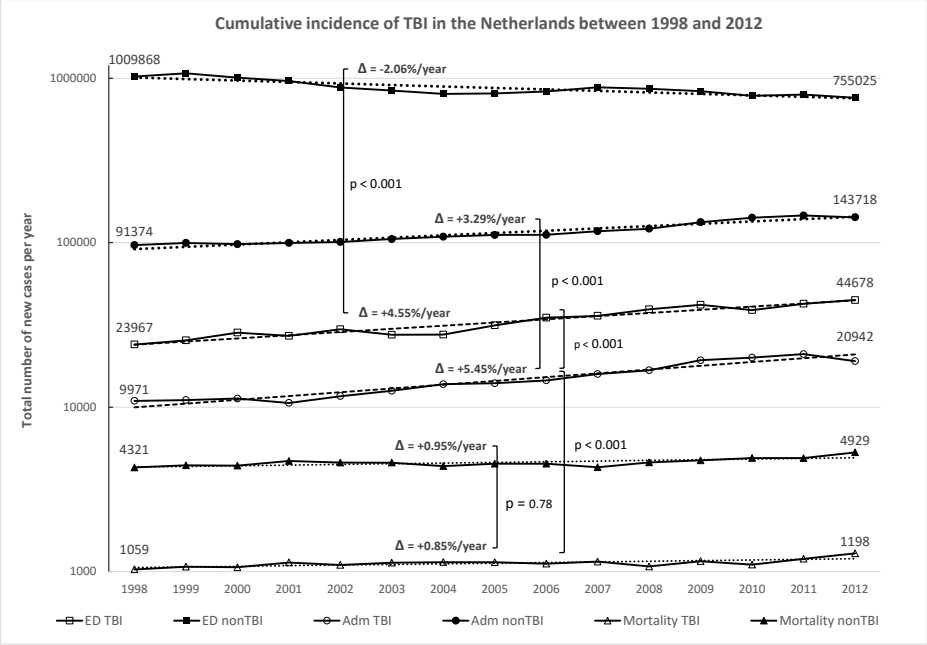

Figure 1

The cumulative incidence of TBI and other injury: ED-visits, admissions and mortality in the Netherlands. A Poisson regression model estimates the best linear fit on logarithmic scale (dotted lines).

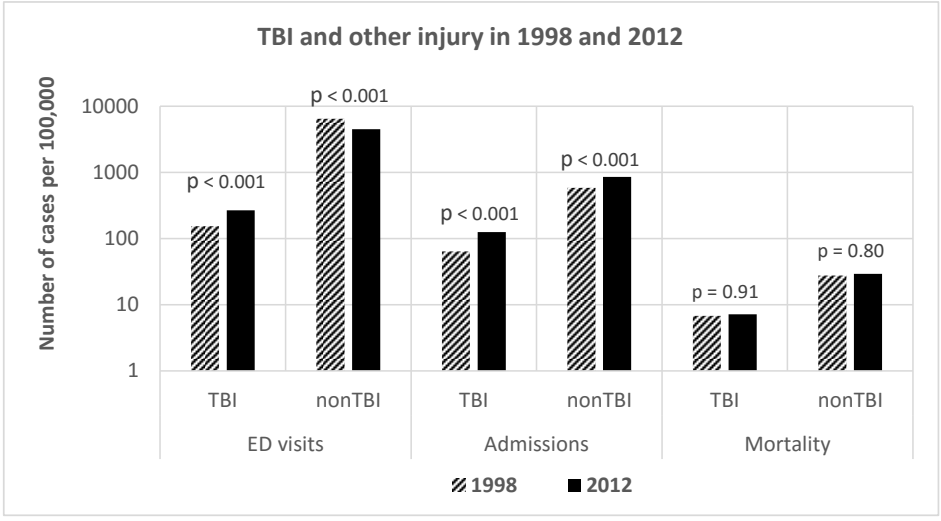

Figure 2

Incidence proportions on a logarithmic scale of TBI and other injury ED-visits, admissions and mortality in the Netherlands, 1998 and 2012 compared.

Table 1. Key figures on traumatic brain injury and other injury between 1998 and 2012 in the Netherlands: emergency department visits, admissions and mortality.

	1998	1999	2000	2001	2002	2003
ED TBI (total)	24,053	25,499	28,415	27,124	29,764	27,555
ED other injury (total)	1,025,522	1,072,796	1,009,383	961,552	878,253	841,291
Admissions TBI (total)	10,928	11,049	11,284	10,608	11,667	12,575
Admissions other injury (total)	96,773	99,688	98,016	99,708	101,038	105,291
Death TBI (total)	1,032	1,071	1,063	1,137	1,097	1,133
Death other non natural causes (total)	4,300	4,434	4,407	4,707	4,600	4,599
ED TBI (65+)	2,270	2,844	3,190	3,196	3,971	4,014
ED other injury (65+)	96,793	103,817	97,048	96,312	93,059	94,644
Admissions TBI (65+)	1,899	1,907	1,932	1,980	2,295	2,606
Admissions other injury (65+)	30,658	31,317	30,739	31,404	31,900	33,942
Death TBI (65+)	349	381	358	399	416	438
Death other non natural causes (65+)	1,837	1,977	1,969	2,237	2,062	2,137
population (total)	15,654,192	15,760,225	15,863,950	15,987,075	16,105,285	16,192,572
population (65+)	2,109,719	2,130,934	2,152,442	2,174,501	2,198,714	2,220,456
% population 65+	13.5%	13.5%	13.6%	13.6%	13.7%	13.7%
% ED TBI 65+/ED TBI total	9.4%	11.2%	11.2%	11.8%	13.3%	14.6%
% Admissions TBI 65+/Admissions TBI total	17.4%	17.3%	17.1%	18.7%	19.7%	20.7%
% Death TBI 65+/Death TBI total	33.8%	35.6%	33.7%	35.1%	37.9%	38.7%

Effects of age

During the study period, the total number of ED visits for TBI by patients aged 65 and older increased from 2270 in 1998 to 10274 in 2012. Besides this absolute increase, there was also a relative increase in ED visits for TBI among those aged 65 and older from 115/100,000 to 388/100,000 per year *(P* < 0.001). For the population younger than 65 years of age, we also observed an increase in TBI-related ED visits; this increase was significantly less (3.1 vs. 9.1% per year*; P* < 0.001) than that in the elderly (from 160/100,000 to 247/100,000 per year; *P* < 0.001). Therefore, the percentage of elderly among patients visiting the ED for TBI increased between 1998 and 2012 (from 9 to 23%).

For TBI-related admissions, the percentage of elderly (≥65) increased from 17 to 28%. Incidence proportions for admissions in the elderly increased from 81/100,000 to 242/100,000 per year *(P* < 0.001). For the population younger than 65 years of age, we also observed an increase in TBI related admissions; this increase was significantly less (3.9 vs. 8.2% per year*; P* < 0.001) than that in the elderly (from 61/100,000 to 104/100,000 per year*; P* < 0.001).

Between 1998 and 2012, the proportion of individuals aged 65 years and older among TBI-related deaths increased from 34% in 1998 to 63% in 2012. In absolute numbers this increase was from 349 in 1998 to 809 in 2012; meanwhile, there was a decrease in TBI-related mortality in the young and middle aged (< 65 years)

2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
27,604	31,439	35,047	35,917	39,391	41,912	38,907	42,516	44,818	499,961
803,445	809,001	831,327	881,374	862,701	834,107	782,246	796,245	761,553	13,150,796
13,799	13,978	14,542	15,897	16,771	19,289	20,022	21,022	19,055	222,486
108,769	111,519	111,667	117,512	121,627	133,218	141,844	146,406	142,693	1,735,769
1,142	1,141	1,117	1,150	1,075	1,157	1,102	1,197	1,292	16,906
4,381	4,531	4,533	4,312	4,612	4,747	4,910	4,900	5,312	69,285
3,834	4,253	5,357	5,659	7,049	7,958	8,351	9,264	10,274	81,484
91,886	94,285	99,633	105,508	105,383	106,745	108,388	115,338	117,514	1,526,353
2,933	3,096	3,416	3,880	4,192	5,374	5,942	6,109	5,395	52,956
34,917	36,150	36,284	38,276	40,360	44,528	49,339	51,202	51,387	572,403
498	520	526	564	535	591	632	708	809	7,724
1,988	2,191	2,351	2,280	2,473	2,535	2,646	2,693	3,000	34,376
16,258,032	16,305,526	16,334,210	16,357,992	16,405,399	16,485,787	16,574,989	16,655,799	16,730,348	
2,251,154	2,288,670	2,330,459	2,368,352	2,414,826	2,471,815	2,538,328	2,594,946	2,716,368	
13.8%	14.0%	14.3%	14.5%	14.7%	15.0%	15.3%	15.6%	16.2%	
13.9%	13.5%	15.3%	15.8%	17.9%	19.0%	21.5%	21.8%	22.9%	
21.3%	22.1%	23.5%	24.4%	25.0%	27.9%	29.7%	29.1%	28.3%	
43.6%	45.6%	47.1%	49.0%	49.8%	51.1%	57.4%	59.1%	62.6%	

from 683 in 1998 to 483 in 2012. When looking at the incidence proportion for TBI mortality, it did not change significantly either for the elderly (from 16/100,000 to 28/100,000 per year; $P = 0.08$) or for the population younger than 65 years of age (from 5/100,000 to 3/100,000 per year; $P = 0.50$). However, the change (3.9% increase per year) in mortality in the population over 65 was significantly more than the change (3.2% decrease per year) in mortality in the population younger than 65 years ($P < 0.001$) (Table 1, Figure 3 and Supplementary Figure 1).

Trauma mechanism

When analyzing different trauma mechanisms in various age groups, it is observed that the increase in TBI-related ED visits is not evenly distributed; road traffic accidents (RTAs) seem to decrease and falls increase as the cause of TBI. Among young and middle aged (< 65 years), Poisson predicted TBI ED visits caused by RTAs decreased from 2682 in 1998 to 2112 in 2012. Translating this into incidence proportion means a decrease from 20 to 15 per 100,000 annually in, respectively, 1998 and 2012. This decrease did not reach statistical significance ($P = 0.39$). The incidence proportion of non-TBI ED visits because of RTAs in the same age group and study period remained more or less stable (from 60 per 100,000 in 1998 to 64 per 100,000 in 2012) ($P = 0.72$). In contrast, Poisson predicted TBI-related ED visits among elderly patients (≥ 65 years) with a fall as the trauma mechanism increased from 853 in 1998 to 4704 in 2012. These figures, translated to incidence proportion, mean an increase from 40 to 173 per 100,000 per year ($P < 0.001$).

The incidence proportion of non-TBI ED visits due to falls in the same age group and study period increased as well but this change was not as impressive; from 1034 to 1436 per 100,000 per year *(P* < 0.001) (Figure 4).

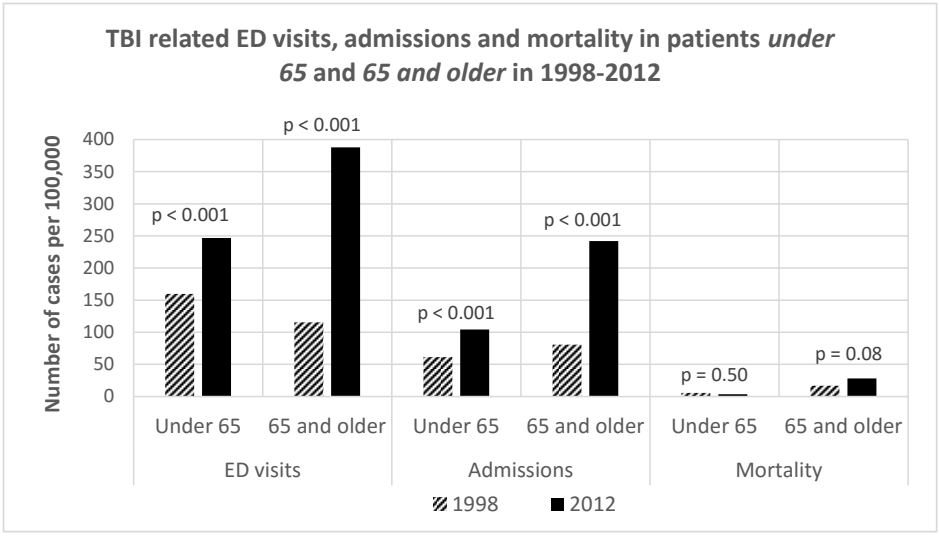

Figure 3

Incidence proportions on a linear scale of TBI ED-visits, admissions and mortality in the Netherlands, population younger than 65 years and 65 years or older compared.

Adjustment for age and gender

When the study population was standardized for age and sex, the TBI-related ED visits and admissions per 100,000 still increased significantly *(P* < 0.001) between 1998 and 2012. The increase was 3.9% for ED visits and 4.6% for admissions annually. With this standardization TBI-related mortality still did not change significantly during the study period *(P* = 0.88) (Supplementary Figure 2).

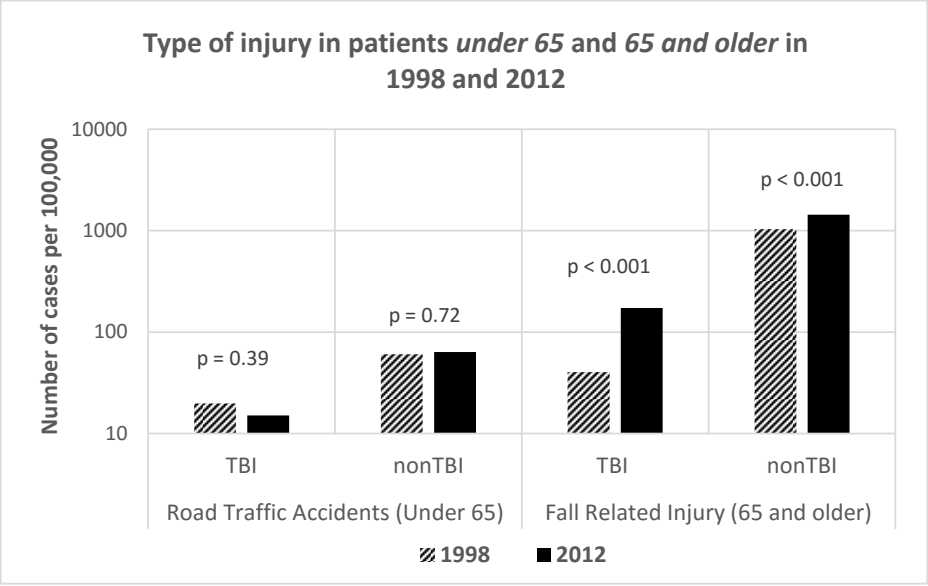

Figure 4

Incidence proportions on a logarithmic scale of ED-visits for TBI and for other injury in the Netherlands. Left: road traffic accidents in population younger than 65 years in 1998 and 2012 compared. Right: falls in population 65 years or older in 1998 and 2012 compared.

Discussion

From 1998 to 2012, there was a significant increase in TBI-related ED visits and hospitalization, whereas TBI-related mortality remained relatively stable. The increase in ED visits and hospital admissions was significantly higher for TBI patients compared with other trauma patients; no such difference was observed for TBI-related deaths compared with other non-natural causes of death. Although the overall TBI-related mortality remained stable there was a change in the demographics of TBI-related mortality. TBI-related deaths in the elderly (≥ 65 years) more than doubled during the study period; TBI related death in the young and middle aged (< 65 years) decreased in contrast.

The observed absolute increase in TBI related ED visits and hospitalizations without a significant increase in mortality rate may be the result of a variety of factors.

First, there is probably an absolute increase of TBI in the population because of ageing of the population and hence more falls and increased use of antiplatelet therapy and anticoagulants. This is also reflected by the observed shift in mortality from mainly young and middle aged to mainly elderly individuals.

Second, a possible explanation for the relative increase in TBI-related ED visits and hospital admissions compared with TBI-related mortality is the increased incidence of less severe TBI. This may be caused by a decrease in traffic accidents and an increase in ground level falls during the study period. This is supported by our finding of a decrease in TBI caused by RTA in the young and middle-aged individuals and a major increase in TBI caused by falls in the elderly. In the late 1990s, traffic accidents caused over 600 TBI-related deaths annually in the Netherlands; by the end of our study period, this number had decreased to about 300.[2] In the same period the number of TBI-related deaths because of falls increased from about 300 to over 650 per year.[2] TBI caused by motorized vehicle accidents result in death approximately four times more often than TBI caused by low-energy falls (6.4 vs. 1.7%).[1] Hence, it makes sense that the number of ED visits and hospitalizations increased much more than the mortality rate during the study period, despite the fact that older patients have a higher TBI mortality than young patients for a given Glasgow Coma Scale score.[17] This is also in line with the result of a recent study from the UK.[18] They studied major trauma patients between 1990 and 2013 and reported a shift in the predominant trauma mechanism from RTAs to falls from less than 2 meter. They also reported a change in the mean age of major trauma patients from 36.1 in 1990 to 53.8 in 2013.

There are several other possible explanations for the increase in TBI-related ED visits and (subsequent) increased admissions that is observed even when correcting for ageing of the population. First, there is probably increased awareness for TBI among the general public, paramedics and general practitioners. Second, the indications for anticoagulant and antiplatelet therapy have expanded in recent years, while these drugs are potential risk factors for traumatic intracranial hemorrhage. This is likely to affect TBI ED visits and admissions even when standardizing for ageing of the population. [6-8, 19-22] Third, fall rates among the elderly may increase and exceed what would be expected merely by ageing of the population. A recent study does support this hypothesis. [23] However, this seems to be in contradiction with the decrease in non-TBI-related ED visits that we observed. Better treatment for osteoporosis could, to some extent, explain this apparent contradiction.[24] Fourth, the change in minor head injury guidelines in the Netherlands in 2010 should be mentioned. Since introduction of the new guidelines an increase in both CT- and hospitalization rate was observed; this could lead to better identification and hence earlier treatment of traumatic intracranial findings.[25,26] Besides better identification and treatment, the threshold for hospitalization might have been lowered during the study period. Our finding that TBI-related admissions increased significantly compared with both TBI-related ED visits and mortality could support this hypothesis. Finally it is possible that the treatment of TBI patients has improved between 1998 and 2012, this could contribute towards a stable TBI-related mortality despite an increasing incidence and is in line with a global trend of decreasing injury-related mortality relative to injury incidence.[27] However, it is not possible to support or refute that conclusion on the basis of our study.

Besides strengths such as size and long duration, this study also has several limitations and the results should be interpreted in the light of these limitations. In contrast to the data on TBI admissions and TBI-related mortality that are (almost) complete, the data regarding TBI-related ED visits are an extrapolation from a limited number (12-15%) of EDs and are indicative only.

The observational nature of this study makes it impossible to draw firm conclusions on the causes of observed changes in TBI-related ED visits, admissions or mortality.

We used existing databases and had to rely on the registered data. Unfortunately, the different databases used did not use the same version of the ICD classification during the study period; the TBI hospitalization and mortality rates were based on ICD9-CM and ICD-10 codes, respectively. This is a limitation when comparing

the different strata of our study. Miscoding cannot be excluded; nonetheless, we do not expect considerable changes in miscoding throughout the years and the changes observed were substantial and consistent and are therefore unlikely to result from miscoding. The TBI hospitalization and mortality rates were based on ICD9-CM and ICD-10 codes; this may result in both false-positive as false-negative cases [5]. An international comparison of absolute numbers mentioned in this article should be done with caution because of the lack of international standardization.

Conclusions

Between 1998 and 2012, the incidence of TBI-related ED visits and hospitalization increased markedly, both in absolute numbers, as compared with other trauma. Despite a 41% reduction in traffic-related deaths in the same period, no reduction in TBI-related deaths was observed. The demographics of TBI-related deaths changed from mainly young and middle-aged individuals (< 65 years) to mainly elderly individuals (≥65 years). These observations are probably caused by a shift in the causative trauma mechanism from mainly traffic accidents (high-energetic trauma) to mainly fall accidents (low-energetic trauma). This hypothesis is supported by our data. However, ageing of the population is not the only cause of the changes observed; the changes observed remained significant when correcting for age and sex. Both policy makers and medical personnel should be aware of these changes in epidemiology. The higher incidence of TBI with a relative stable mortality rate highlights the importance of clinical decision rules to identify patients with a high risk of poor outcome after TBI.

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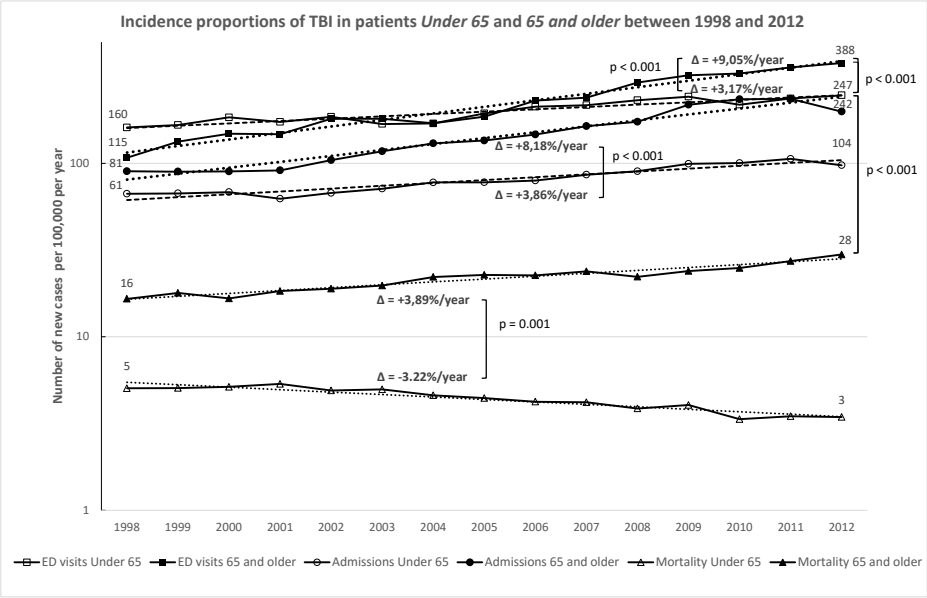
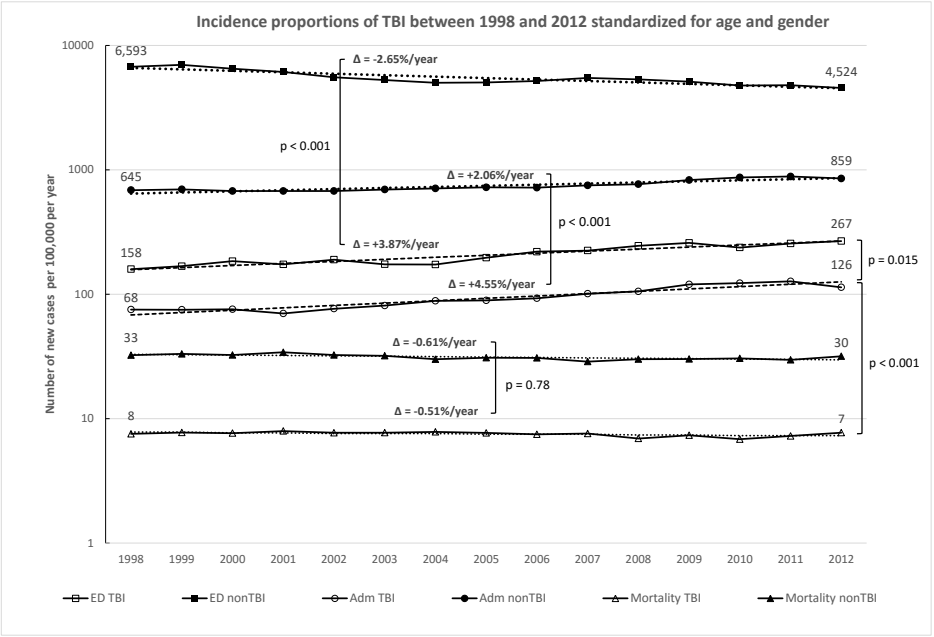
Supplementary Material



Supplementary Figure 1

Incidence proportions of TBI: ED-visits, admissions and mortality in the Netherlands, population < 65 years and ≥ 65 years compared. A Poisson regression model estimates the best linear fit on logarithmic scale (dotted lines).



Supplementary Figure 2

Incidence proportions standardized for age and gender of TBI and other injury: ED-visits, admissions and mortality in the Netherlands. A Poisson regression model estimates the best linear fit on logarithmic scale (dotted lines).