Changing Epidemiology of Traumatic Brain Injury Among the Working-Aged in Finland: Admissions and Neurosurgical Operations

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Ethics approval and consent to participate

Because this was a retrospective nationwide registry study, the requirements for permissions from individual hospital review boards and informed consent were waived by the law and participants were not contacted. The collection and reporting of data within the included registries are mandated by law; therefore, the data from these registries provides a full picture of the Finnish population. The legal basis for the processing of personal data is public interest and scientific research (EU General Data Protection Regulation 2016/679 (GDPR), Article 6(1)(e) and Article 9(2)(j); Data Protection Act, Sections 4 and 6).

Consent for publication

All authors attest to the validity of data and the text, and agree on publication.

Availability of data and materials

The data underlying this article were provided by the Findata by permission. The Data is available from Findata (findata.fi) by permission.

Conflicts of interest

Dr Kytö has received a scientific consultancy fee (AstraZeneca), speaker fee (Bayer, Astra- Zeneca, and Boehringer Ingelheim), and travel grants and congress sponsorship (AstraZeneca, Boehringer Ingelheim, Bayer, and Pfizer); Dr Rautava has received speaker fee and travel grant (Roche Oy); Dr Sipilä has received honoraria (Merck, Pfizer, and Sanofi), a consultancy fee (Rinnekoti Foundation), travel grants and congress sponsorship (Abbvie, Orion Pharma, Merck Serono, Sanquin, Lundbeck, and Novartis), and holds shares (Orion Corporation); Dr. Posti and Dr. Luoto do not have conflicts of interest.

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Author contributions

- JPP: Study concept or design; drafting the first version of the manuscript; interpretation of data
- TML: Drafting and revision of the manuscript for content; interpretation of data
- JOTS: Drafting and revision of the manuscript for content; acquisition of data; interpretation of data
- PV: Drafting and revision of the manuscript for content; acquisition of data; interpretation of data
- VK: Study concept or design; main data analysis; drafting and revision of the manuscript for content

Abstract

Background: Recent studies from Finland have highlighted an increase in the incidence of traumatic brain injuries (TBI) in older age groups and high overall mortality. We performed a comprehensive study on the changing epidemiology of TBI focusing on the acute events in the Finnish working-age population.

Methods: Nationwide databases were searched for all emergency ward admissions with a TBI diagnosis for persons of 16–69 years of age during 2004–2018.

Results: In the Finnish working-age population, there were 52,487,099 person-years, 38,810 TBI-related hospital admissions, 4,664 acute neurosurgical operations (ANO), and 2,247 cases of in-hospital mortality (IHM). The TBI-related hospital admission incidence was 94/100,000 person-years in men, 44/100,000 in women, and 69/100,000 overall. The incidence rate of admissions increased in women, while in men and overall, the rate decreased. The incidence rate increased in the group of 60–69 years in both genders. Lowest incidence rates were observed in the age group of 30–39 years. Occurrence risk for TBI admission was higher in men in all age groups. Trends of ANOs decreased overall, while decompressive craniectomy was the only operation type in which a rise in incidence was found. Evacuation of acute subdural hematoma was the most common ANO. Mean length of stay and IHM rate halved during the study years.

Conclusions: In Finland, the epidemiology of acute working-aged TBI has significantly changed. The rates of admission incidences, ANOs and IHM nowadays represent the lower end of the range of these acute events reported in the western world.

Key words: traumatic brain injury; incidence; neurosurgical operations; in-hospital mortality; length of stay

Background

The World Health Organization considers traumatic brain injury (TBI) a major public health problem worldwide due to the high incidence across the continents and high socioeconomic burden to societies. [1] It is estimated that 50 million people in the world suffer a TBI each year and one in two people sustains a TBI in their lifetime. [2] TBI is a major cause of lost working years, disability and mortality in all age groups. [1,3]

In the recent decades, polarization of TBI-related admissions to the earliest and latest years of life have increased in the human life cycle. [4,5] This has led to the emergence of epidemiological studies of TBI in different countries across the world. A decrease in the incidence of TBI has been observed in the United States during this millennium [6–8] and a current living systematic review article suggests a similar trend in Europe. [9] Methodological heterogeneity of the epidemiological TBI studies makes it difficult to compare and apply the results in practice. Substantial differences in inclusion criteria and case definitions has been observed. [9] In addition, overlapping cohorts and, on the other hand, gaps between cohorts hinder the assessment of the overall picture and changes in incidences over time.

We have recently reported that the rate of geriatric TBI-related hospital admissions [10] and the mean age of neurosurgically operated TBI patients is increasing [11]. Concurrently, the rate of acute neurosurgical operations (ANO) and hospital length of stay (LOS) are decreasing among older Finnish citizens. [10,11] The earlier Finnish studies examining working-age population in this regard are based on data from 1970–2005. [12–14] On the basis of the above-mentioned studies, it is impossible to draw conclusions about the current TBI incidence and epidemiological trends among working-age people.

The characterization of the European epidemiology of TBI is incomplete. As the current research evidence from Finland has mainly highlighted an increase in the incidence of TBI in older age groups [10,15] and high overall mortality [5,16], we devised a comprehensive study on the changing epidemiology of TBI in the Finnish working-age population over the past 15 years. We focus on the acute events including incidence of TBI-related admissions, ANOs, LOS and in-hospital mortality (IHM) in every unit providing healthcare services in Finland to fill the current knowledge gap.

Methods

Study population and data search

All emergency hospital ward admissions with TBI (ICD-10 codes S06.*) as the primary diagnosis for patients aged 16–69 years in Finnish private and public hospitals and healthcare ward units between January 1, 2004 and December 31, 2018 were collected from the Care Register for Health Care. This mandatory by law database held by the National Institute for Health and Welfare (THL), Helsinki, Finland captures all hospital discharges in Finland and includes information on performed surgical operations. Transfers between and within healthcare providers related to a particular admission episode were combined as one admission. One admission per patient per calendar year was included. Age-, sex-, and calendar year specific general population demographic data was obtained from Statistics Finland (Helsinki, Finland). The background population at risk consisted of 52,487,099 person-years. The person-years of each study year were estimated by population at the end of each year. Patients belonging to different age groups were calculated separately for each year. IHM was defined as death during a hospitalization episode.

The neurosurgical procedures according to the Nordic Medico-Statistical Committee (NOMESCO) classification [17] included in the search were AAA27, AAD00, AAD05, AAD10, AAD12, AAD15, AAD16, AAD30, AAD40, AAD42,

AAD99, AAF00, AAF05, AAF15, AAF20, AAF25, AAF30, AAF35, AAF40, AAF45, AAF50, AAF99, AAK00, AAK10, AAK20, AAK30, AAK40, AAK80, and AAK99. Of these procedure types, AAD00 [evacuation of epidural hematoma (EDH)], AAD05 [evacuation of subdural hematoma (SDH)], and AAD15 [evacuation of intracerebral hematoma (ICH)] are acute procedures and include a major craniotomy and intracranial hematoma evacuation, whereas AAK80 is decompressive craniectomy—utilized in the acute setting. Patients with evacuation of chronic subdural hematoma (ICD-10 code S06.5 or I62.0 with operational codes AAD10 and AA12) within initial admission were excluded. The study was approved by THL (permission no. THL/2245/5.05.00/2019). Legal basis for the processing of personal data is public interest and scientific research (EU General Data Protection Regulation 2016/679 (GDPR), Article 6(1) and Article 9(2)(j); Data Protection Act, Sections 4 and 6. Informed consent was waived due to the retrospective nature of the study and the participants were not contacted.

Statistical analysis

Differences in continuous variables were analyzed with the t-test and differences in categorial variables with Chi-squared test. Annual incidence was studied with negative binomial regression modelling using logarithm of the background population as an offset parameter[18]. Annual trends in dichotomial variables were studied with Cochrane-Armitage trend test. Admission duration was studied using linear regression modelling (log-transformed and standardized dependent variable). Significance was inferred at $p<0.05$. The SAS system version 9.4 (SAS Institute Inc., NC, USA) and GraphPad Prism version 8.0 (Graphpad Software, CA, USA) were used for the statistical analyses.

Ethical approval and informed consent, availability of data and materials

Because this was a retrospective nationwide registry study, the requirements for permissions from individual hospital review boards and informed consent were waived by the law and participants were not contacted. The data underlying this article were provided by the Findata by permission. The Data is available from Findata (findata.fi) by permission.

Results

In the Finnish working-age population during 2004–2018, there were 52,487,099 person-years, 38,810 TBI-related hospital admissions (mean age=46.4 years, men=69%), 4,664 ANOs (80% men), and 2,247 cases of IHM (84% men). In men, 85% (n=24,847) of patients had one TBI-related hospital admission, 8% (n=3,412) had two TBI-related admissions, and 4% (n=1,141) had three or more admissions. In women, 91% (n=11,732) of patients had one TBI-related hospital admission, 8% (n=988) had two TBI-related admissions, and 2% (n=231) had three or more admissions. In men, the maximum number of admissions in one patient was 13, while in women the figure was seven. Reoccurring TBI was more common in men ($p<0.0001$).

Incidence rates and trends

During the study years, the incidence-rate of TBI-related hospital admissions was 94/100,000 person-years in men, 44/100,000 in women, and 69/100,000 overall. Incidence rates were highest in the age group of 60–69 years in both genders and overall. Lowest incidence rates were observed in the age group of 30–39 years. The incidence of TBI admissions was higher in men in all age groups (Table 1).

During the study period, the incidence rate of TBI-related hospital admissions increased in women, while in men and overall, the incidence rate decreased. The gender-specific trends show that in women, the admission incidence rate increased in the age group of 60–69 years but remained stable in the age group of 16–59 years. In men and overall, there was no change in the incidence rate in the age group of 16–29 years, whereas in the age group of 30–59 years, the incidence rate decreased, and in the age group of 60–69 years, the incidence rate increased (Table 2 and Figure 1).

Acute neurosurgical operations and trends

During the study years, there were 3,702 ANOs in men and 962 in women (in 11% of all hospitalized due to TBI), and decreasing trend was observed in men, women and overall (all: $p<0.001$). There were 509 evacuations of EDH in men and 116 in women (in 1.5% of all hospitalized), with decreasing trends in both genders and overall (men: $p<0.001$; women: $p=0.044$; overall: $p<0.001$). In terms of evacuations of SDH, there were 1,715 operations in men and 483 in women (in 5.2% of all hospitalized) with decreasing trends in both genders and overall (all: $p<0.001$). There were 456 evacuations of ICH in men and 95 in women (in 1.3% of all hospitalized). A decreasing trend was observed in men and overall (both: $p<0.001$), but in women, there was an increasing trend ($p=0.004$). Regarding DC, there were no operations until 2008. From that year, there were 204 operations in men and 45 in women (in 0.6% of all hospitalized). A decreasing trend was observed in men (men: $p<0.001$), but in women and overall, there was an increasing trend (women: $p=0.004$; overall: $p<0.001$) (Figure 2).

Length of stay and in-hospital mortality

Mean LOS was 18.3 (±78.7) days in men, 10.7 (±51.4) in women and 16.0 (±71.6) overall with decreasing trend in every group ($p<0.001$). The mean LOS decreased by more than half from 2004 (22.5 days) to 2018 (9.1 days). The result was not affected by adjustment with acute neurosurgical operations. Rate of cases of IHM was 1,811 in men and 436 in women. IHM occurred in 6.2 % of hospitalized men, in 3.3 % of hospitalized women and 5.3 % of all hospitalized patients. Decreasing trend was observed over the study years (men, women and overall: $p<0.001$). The mean IHM percentage decreased by half from 2004 (6.9%) to 2018 (3.6%) (Figure 3).

Discussion

This was a nationwide population-based study examining the epidemiology of acute events of TBI among the working-age population in Finland during 2004–2018. The main findings were that i) TBI-related hospital admission incidence was 94/100,000 person-years in men, 44/100,000 in women, and 69/100,000 overall, ii) the incidence rate of admissions is increasing in women, while in men and overall, the rate is decreasing, iii) the incidence rate is increasing in the group of 60–69 years in both genders, iv) trends of ANOs is decreasing overall, while DC was the only operation type in which a rise in incidence was found, v) LOS is decreasing, and vi) incidence rate of IHM is decreasing.

The incidence rates of TBIs are difficult to compare between individual studies and reviews due to inconsistent inclusion criteria and case ascertainment. Nevertheless, based on the detailed systematic reviews, it has been concluded that there is no ongoing decrease in the overall European TBI incidence rate. [9,19] However, it is known that in Finland, as in many other countries, the incidence rate of TBIs among older people is currently increasing. [10,20–22] On the other hand, we have recently reported that at the same time, TBIs in leisure time are becoming more common among young and healthy individuals. [23]

Significant variation in the incidence rates of TBI-related admissions in Europe has been reported depending on the country, region, study period, and age group. Reported incidence rates in regional populations or hospital catchment areas have previously been reported to be somewhat higher than in nationwide studies. [9] Studies may have been conducted in smaller regions or in a hospital district because that region or hospital contains a tertiary care center with emergency, critical care, and neurosurgical services. Data from local databases may be more granular and cover a larger number of patients because of specific search capabilities. However, nationwide studies are based on uniform coding systems and may be more reliably comparable than regional studies.

In nationwide studies covering all age and severity groups, TBI admission incidence rates between 47–694/100,000 have been reported. [9] In these studies, the lowest reported rate is from Spain (years 2000–2009)[24] and highest from the Republic of San Marino (years 1981–1982) [25]. In regional studies including all TBI cases, a range of 83–849/100,000 has been reported, the lowest being from Oslo, Norway [26], and the highest from the Comune di Ravenna, Italy [27]. In an earlier Finnish study, incidence rates of 122/100,000 for males, 80/100,000 for females, and 101/100,000 overall during the years 1991–2005 have been reported. [14] In a cross-sectional study including TBI-related hospital admissions from 24 European countries in 2012, an incidence rate of 295/100,000 for all age groups in Finland was reported. [5]

Among the working-aged in Finland, we observed that TBI-related hospital admission incidence rate was 94/100,000 person-years in men, 44/100,000 in women, and 69/100,000 overall in 2004–2018. The incidence rates showed decreasing trends in men and overall, while in women, the incidence rate was on the rise. Among the working-age population, the earlier Finnish study [13] covering the years 1991–2005 show slightly higher incidence rates in all other age groups excluding the age group of 60–69 years, which is higher in this study. Accordingly, we also observed an ongoingly increasing trend in this age group.

There are multiple regional studies on TBI admission incidence rates, but nationwide studies are scarce in this millennium in the working-aged. In the Netherlands, the hospital admission incidence rates among the working-aged between 2010 and 2012 have been 156–268/100,000. [28] In Austria, the corresponding figures were 256–469/100,000 in 2009–2011.[29] In Sweden, the admission incidence rates are somewhat higher than in the current study, but they show similar declining trends among the working aged in 1987–2010. However, the study by Pedersen et al. reports the rates only in a graph thus exact figures are not available. [30] In Spain, the admission incidence rates among working-aged are lower between 2000 and 2009 than in this study. [24] Comparison with other studies is difficult due to the aforementioned matters. Yet our findings fall within the ranges reported by studies in other European countries, more specifically at their lower limits. What seems to be common is that the hospital admission incidence of working-age people is declining.

We observed a percentage of ANOs of 11% among the hospitalized working-age population. This figure falls below the range of earlier studies. [31–33] A major reason for this finding is that the current study is population-based and thus covers all Finnish healthcare units—even the small health centers, and regional, central, and private hospitals that do not have neurosurgical services. We observed a declining trend in all ANOs overall but not in case of DCs. This is in accordance with the finding that the overall admission incidence rate in the working-aged is declining, which intuitively also affects the need for ANOs. The result reflects the larger picture that in the European TBI spectrum, the incidence rate of mild TBIs is on the rise due to injuries among the aging population. [9,10,34] In terms of DC, the current evidence leaves little uncertainty about the life-saving effect of the operation in patients with severe TBI and intractable intracranial hypertension that does not respond to maximal medical therapy. However, there is a risk that the operation may result in severe disability and dependence on others. DC was initially used over a century ago, and the operation came back to use in this millennium. [35,36] The operation saw its advent in Finland before the two major clinical randomised controlled trials investigating survival and neurological outcome after DC were published. [37,38] Rate of DCs remains on a growing trend though its benefits on long-term functional outcome remain debatable in TBI.

There was a strong declining trend in LOS—the figure decreased by more than half during the study era being 9 days in 2018. The mean LOS is still considerably higher than in a recent multicenter study, CENTER-TBI, including 65 centers in Europe and Israel [31], but this is probably due to the methods of the current study as we combined the treatment episodes. We also observed a drastic decrease in the rate of IHM during the study years, the mean percentage being lower than the overall IHM of 8.1% in the CENTER-TBI study. This finding can be partly explained by the studied age group in the current study. Plausible reason for the reduced length of stay is related to the higher and increasing incidence of TBIs in the oldest age group, which in turn is related to the increasing proportion of mild TBIs. These findings are in line with the earlier addressed observations of decreasing rates of admission incidence and ANOs in this study reflecting the changing epidemiology of TBI in Finland. Nevertheless, we have recently reported that the rate of trauma craniotomies has decreased and a concurrent decrease in mortality and increase in mean age is observed in older patients (≥70 years) in Finland during 2004–2018. [11] This, in turn, shows that the changes in the TBI epidemiology in different age groups is complex and treatment practices are likely to have influenced the outcome alongside demographic changes.

The strengths of this study are the comprehensive Finnish obligatory databases and nationwide population-based design. Moreover, Finland is a country where the social and health care system is tax-funded and thus equally accessible. These results can be considered as pure population-based observations on the acute events of Finnish TBI epidemiology. To avoid overestimation of the admission incidences, we combined transfers between and within healthcare units related to a particular admission episode as one admission. This approach most likely results in significantly lower indices than those that were reported in the European cross-sectional study in which this combination was not performed. [5] There are also limitations that deserve attention. Our approach is not free from underestimation: we only studied those TBI cases who were admitted to private and public hospitals and healthcare ward units. We did not include patients who did not need admission to a ward and were discharged. Also, those patients who died before hospital admission were not included in this study. In case of ANOs, the current rates represent an underestimation too, because most of the intraparenchymal intracranial pressure devices (AAA27) and some of the extraventricular drains (AAF00) are inserted bedside in the Finnish intensive care units and thus the procedures are not recorded in the operation theater databases. We included all cranial neurosurgical procedures as other ANOs than those that were studied in detail. Many of them are not typical ANOs, but we wanted to include them to give a better overall picture, as they were nevertheless performed during the treatment episode associated with acute TBI hospitalization. We did not review death certificates so we cannot verify that all cases of IHM were TBI-related—however, they occurred during the acute hospitalization.

Conclusions

The changes in the Finnish TBI epidemiology have been substantial in the working-aged. A declining trend was observed overall in hospital admission incidence rates. However, the incidence rate increased in the group of 60–69 years in both genders. The lowest incidence rates were observed in the age group of 30–39 years. Trends of ANOs decreased overall, while decompressive craniectomy was the only operation type in which a rise in incidence was found. The mean length of stay and the rate of IHM halved during the study years. Future research will be tasked with examining how these changes have affected the quality of life of survivors and what kind of sosioeconomic effects the changes have had on the society.

Figure captions

Figure 1. Admission incidence rates in different age groups over the years 2004–2018.

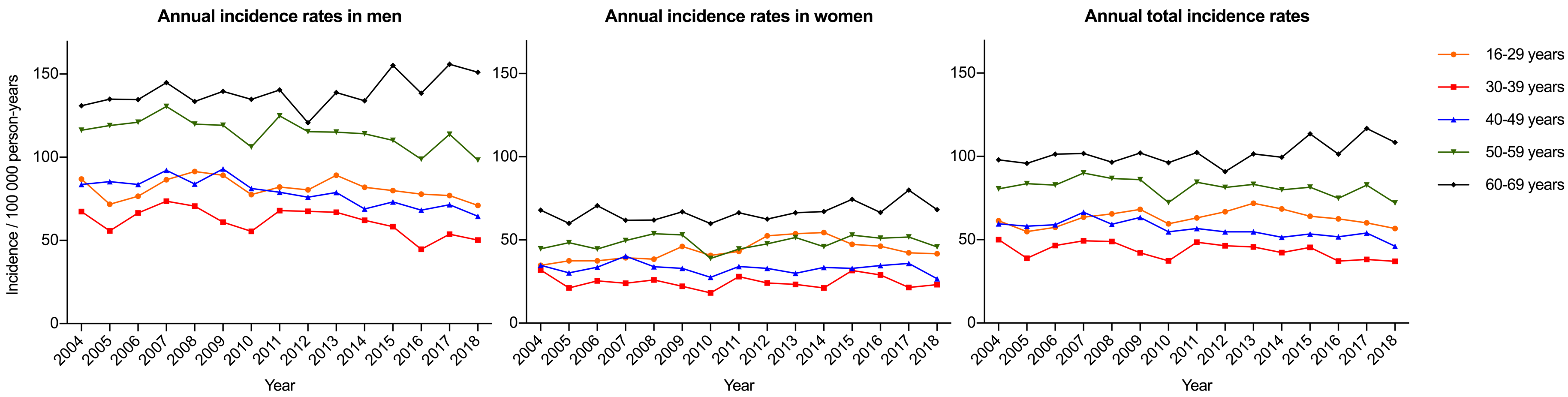

Figure 2. Rates and percentages among hospitalized of acute trauma operations in 2004–2018. The lines represent number of cases per year (left y-axis), and the bars represent the percentage of neurosurgical interventions among the hospitalized patients (right y-axis).

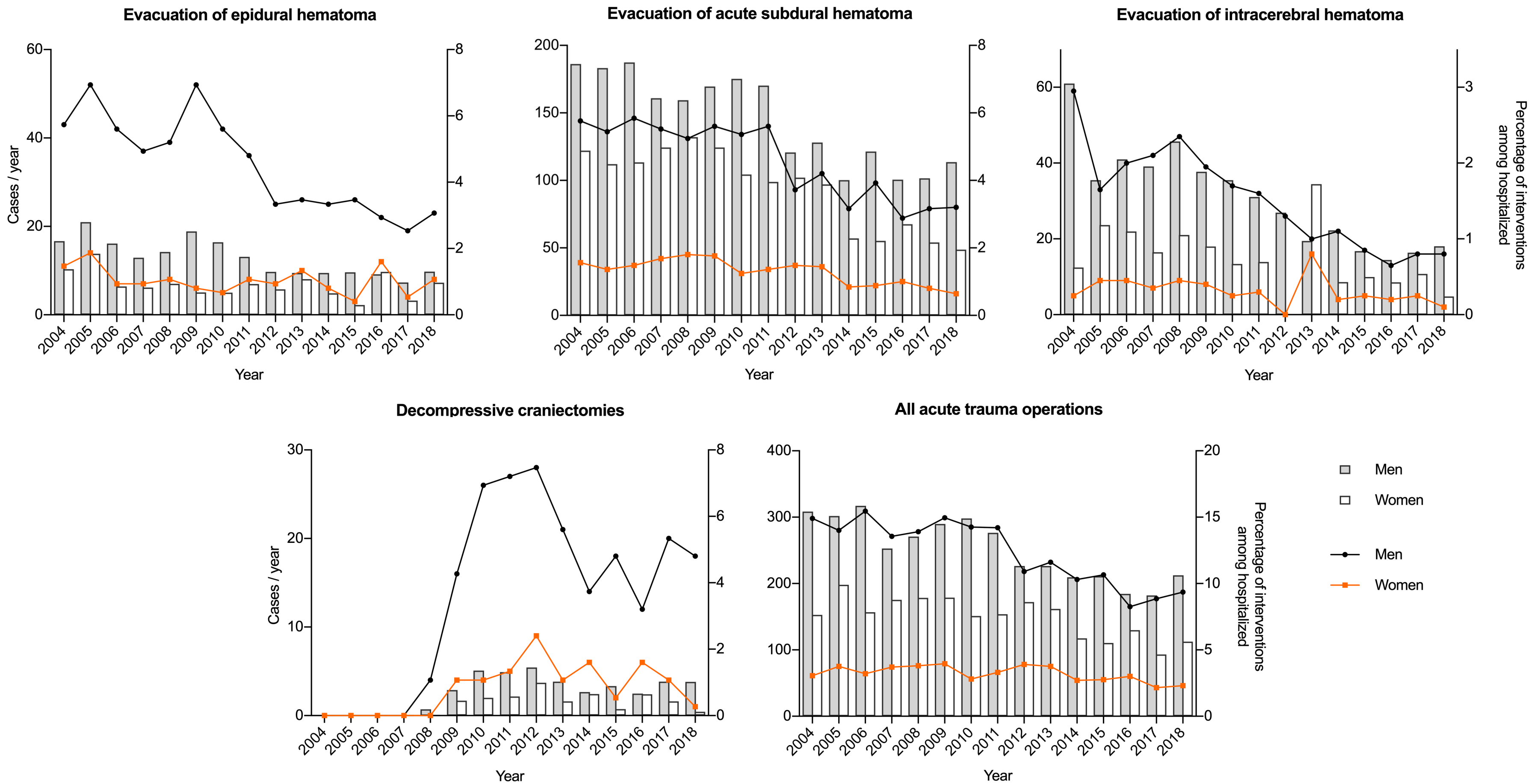

Figure 3. Mean length of stay (95% confidence intervals) and rates of in-hospital mortality in 2004–2018. On the right, the lines represent number of cases per year (left y-axis), and the bars represent the percentage of deaths among the hospitalized patients (right y-axis).

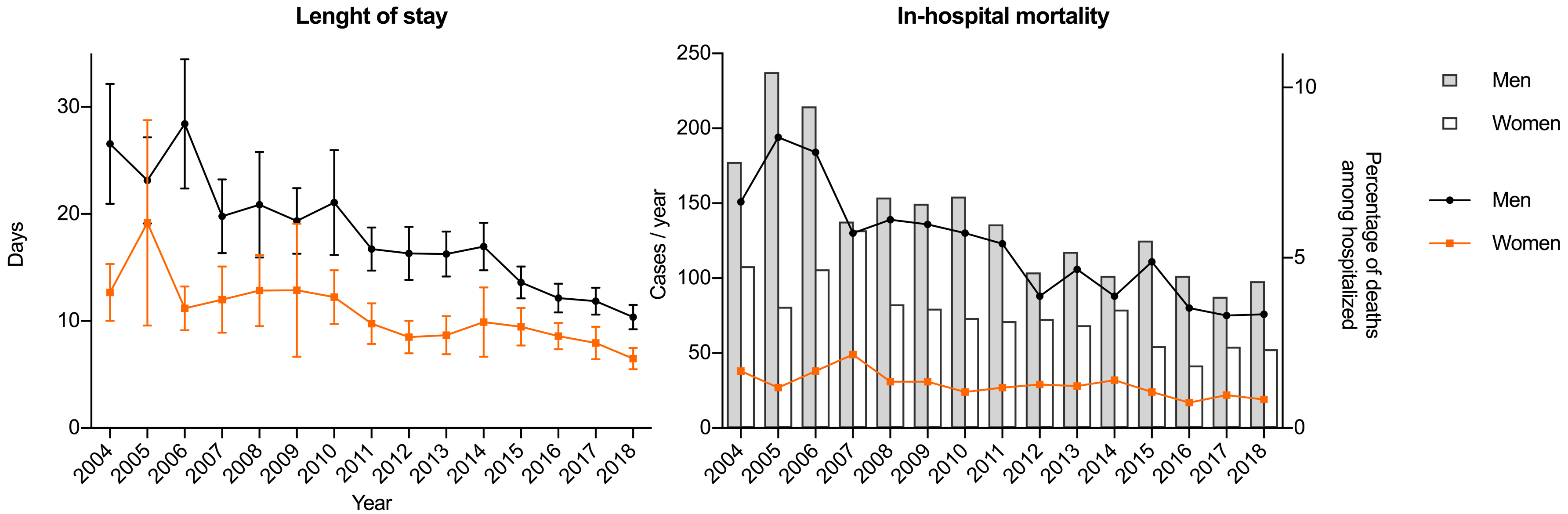

Table 1. Incidence rates by age groups and incidence risk between genders.

	Men			Women			Total			Incidence risk men vs. women		
Age	n	Population	Incidence	n	Population	Incidence	n	Population	Incidence	IRR	95% CI	p
16–29	5799	7131056	81.32	2973	6796018	43.75	8772	13927074	62.99	1.74	1.49–2.05	<0.0001
30–39	3182	5190693	61.30	1217	4919033	24.74	4399	10109726	43.51	2.48	2.25–2.73	<0.0001
40–49	4284	5406097	79.24	1731	5247293	32.99	6015	10653390	56.46	2.41	2.27–2.55	<0.0001
50–59	6577	5718688	115.01	2773	5745182	48.27	9350	11463870	81.56	2.38	2.25–2.51	<0.0001
60–69	6795	4868160	139.58	3479	5198813	66.92	10274	10066973	102.06	2.09	2.00–2.18	<0.0001
Total	26637	28314694	94.07	12173	27906339	43.62	38810	56221033	69.03	2.15	2.08–2.24	<0.0001

n, number of cases; population, background population at risk; IRR, incidence risk ratio

Table 2. Estimated annual trends in incidence of TBI-related hospital admissions during the study period.

	Men				Women				Total			
Age	IRR	CI95% low	CI95% high	p	IRR	CI95% low	CI95% high	p	IRR	CI95% low	CI95% high	p
16–29	0.996	0.978	1.015	0.689	1.027	0.994	1.061	0.113	1.010	0.995	1.024	0.206
30–39	0.982	0.970	0.994	0.011	0.997	0.980	1.016	0.780	0.987	0.980	0.995	0.001
40–49	0.980	0.973	0.987	<0.0001	0.995	0.984	1.006	0.356	0.984	0.980	0.989	<0.0001
50–59	0.989	0.982	0.995	0.003	1.004	0.995	1.014	0.399	0.994	0.989	0.998	0.005
60–69	1.009	1.005	1.013	0.030	1.010	1.002	1.018	0.032	1.009	1.005	1.013	<0.0001
Total	0.992	0.988	0.996	0.000	1.008	1.002	1.013	0.005	0.998	0.995	1.001	0.161

IRR, incidence risk ratio

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