A population-based study of fall-related traumatic brain injury identified in older adults in hospital emergency departments

Michael D. Cusimano, MD, PhD,¹⁻³ Olli Saarela, PhD,³ Kirsten Hart, BSc,^{1,2} Shudong Zhang, MD,^{1,2} and Steven R. McFall, MSc⁴

¹Division of Neurosurgery, Department of Surgery, St. Michael's Hospital, University of Toronto; ²Injury Prevention Research Office, Li Ka Shing Knowledge Institute, Keenan Research Centre, University of Toronto; ³Dalla Lana School of Public Health, University of Toronto; and ⁴Injury Section, Centre for Surveillance and Applied Research, Public Health Agency of Canada, Ottawa, Ontario, Canada

OBJECTIVE The purpose of this study was to examine the population-based trends and factors associated with hospitalization of patients with traumatic brain injury (TBI) treated in the Emergency Department (ED) among those 65 years and older. The implications of these trends for neurosurgery and the broader society are discussed.

METHOD With a national, mandatory reporting system of ED visits, the authors used Poisson regression controlling for age and sex to analyze trends in fall-related TBI of those aged 65 years and older between 2002 and 2017.

RESULTS The overall rate of ED visits for TBI increased by 78%—from 689.51 per 100,000 (95% CI 676.5–702.8) to 1229 per 100,000 (95% CI 1215–1243) between 2002 and 2017. Females consistently experienced higher rates of fall-related TBI than did males. All age groups 65 years and older experienced significant increases in fall-related TBI rate over the study period; however, the highest rates occurred among the oldest individuals (90+ and 85–89 years). The hospital admission rate increased with age and Charlson Comorbidity Index. Males experienced both a higher admission rate and a greater percentage change in admission rate than females.

CONCLUSIONS Rates of ED visits for fall-related TBI, hospitalization, and in-ED mortality in those aged 65 years and older are increasing for both sexes. The increasing hospital admission rate is related to more advanced comorbidities, male sex, and increasing age. These findings have significant implications for neurosurgical resources; they emphasize that health professionals should work proactively with patients, families, and caregivers to clarify goals of care, and they also outline the need for more high-level and, preferably, randomized evidence to support outcomes-based decisions. Additionally, the findings highlight the urgent need for improved population-based measures for prevention in not only this age demographic but in younger ones, and the need for changes in the planning of health service delivery and long-term care.

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KEYWORDS traumatic brain injury; TBI; falls; elderly; trends; hospitalization; emergency

It is estimated that in the United States alone, 1.5 million people suffer annually from a traumatic brain injury (TBI), and almost 5.3 million people live with the associated long-term physical, cognitive, and psychological disabilities, leading to projected yearly costs of \$56 billion.¹ This \$56 billion, however, underestimates the true cost of TBIs, because it excludes injuries treated solely in the Emergency Department (ED), other nonhospital medical costs, and indirect costs borne by family and friends.¹ Moreover, TBI is the second most prevalent neurological

condition in Canada,² and there is increasing evidence that repeated TBIs may also be linked with neurodegenerative conditions like Parkinson disease³ and dementia.⁴

In people older than 65 years, falls account for approximately 70% of TBIs.⁵ Between 2015 and 2050, the proportion of the world's elderly population is estimated to virtually double—from 12% to 22%.⁶ The rapidly aging population raises concern regarding TBI rates among the elderly. Indeed, our previous research reported a 24% increase in TBI hospitalization rates among adults aged 65

ABBREVIATIONS CCI = Charlson Comorbidity Index; CDC = Centers for Disease Control and Prevention; ED = Emergency Department; NACRS = National Ambulatory Care Reporting System; TBI = traumatic brain injury.

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years and older in Canada between 2006 and 2011 and that falls were responsible for 82% of hospitalizations among individuals 65 years and older.⁷ Further supporting these concerns, other research has suggested that up to one-third of the elderly population experiences a fall each year; 10% of people in the elderly population who experience a fall sustain a serious injury.⁸

As people live longer there are greater numbers of active older adults who tend to accumulate comorbid conditions as they age. Prior literature has found that age plays a crucial role in an individual's fall risk and the severity of the injury. In older populations, females may have a higher fall risk, and in addition to fall and mortality risk, the severity of the injury can vary with age and sex.^{5,9–11} However, despite the growing prevalence and economic burden of fall-related TBI, few studies have focused on the temporal and seasonal trends of TBI. How predictors of falls and the outcomes from these falls in older age groups have changed over time is not well understood and reflects a gap in current literature. A better understanding of this would allow policy makers and others to organize concerted prevention efforts and plan acute and rehabilitative healthcare accordingly.

The current study uses ED visit data from 2002 to 2017 to identify fall-related TBI in individuals aged 65 years and older in Ontario, Canada's most populous province. These data will be analyzed to identify any significant trends and fall-related TBI rates across age, sex, and comorbidity index, which have not been previously explored. The aims of this study are 4-fold: 1) to describe epidemiological trends for fall-related TBI in Ontario, Canada; 2) to identify key demographics at risk of fall-related TBI; and 3) to investigate factors associated with hospitalization following an ED visit for TBI; and 4) to assess the implications of these findings on health policy and injury prevention.

Methods

Study Design and Setting

We conducted a population-based descriptive epidemiological study of patients 65 years and older who visited EDs in Ontario for a TBI between 2002 and 2017. The study was approved by the Research Ethics Board at St. Michael's Hospital. Data were used from the National Ambulatory Care Reporting System (NACRS), which is a mandatory, incidence-based reporting database for all EDs and ambulatory care centers in Ontario.¹² The NACRS captures more than 98% of all ED visits in Ontario and gathers information on patient identities (such as unique ID, health card number, and postal code), demographics (such as sex, birth date, and educational level), *International Classification of Diseases, Tenth Revision* (ICD-10) diagnosis codes, external causes of injury codes, ambulance transport, and visit disposition.¹³

Study Population

The study's sample includes all ED visits among individuals aged 65 years and older in Ontario, Canada, between March 1, 2002, and March 31, 2017, from NACRS data that contained an ICD-10 code indicating a TBI. TBIs

were defined using ICD-10 codes designating the nature of the injury according to the US Centers for Disease Control and Prevention (CDC): open wound of head (S01 [0.7, 0.8, 0.9]); fracture of skull and facial bones (S02 [0.0, 0.1, 0.7–0.9]); intracranial injury (S06.0–S06.9); crushing injury of head (S07 [0.1, 0.8, 0.9]); unspecified injury of head (S09.7–S09.9); injuries involving head with neck (T02.0, T04.0, T06.0); and a sequela of injuries of the head (T90 [0.2, 0.5, 0.8, 0.9]).¹⁴ Patients were only included in the study if the TBI was fall related. The CDC's External Cause of Injury Matrix¹⁵ was used to classify each TBI as fall related. Patients who registered at the ED but left without receiving treatment were excluded from the study.

The Charlson Comorbidity Index (CCI) for each patient was found using a proven ICD-10 coding algorithm.¹⁶ The CCI is a widely accepted technique to gauge a patient's disease burden, composed of 19 clinical conditions that are noteworthy predictors of mortality, including liver disease, congestive heart failure, and renal disease.¹⁷ The total score was individually computed for each patient by searching for an ICD-10 code coinciding to their conditions. Ambulance transport and visit disposition acted as proxies for injury severity, because traditional measures of severity (e.g., Injury Severity Score, Abbreviated Injury Scale, Glasgow Coma Scale) were either missing or not reported in the majority of cases.

Measurements and Data Analysis

Descriptive statistics were used to classify the study cohort. Age groups were divided by 5-year increments: 65–69, 70–74, 75–79, 80–84, 85–89, and 90+ years. Age-specific and sex-specific rates were calculated using Ontario population data from Statistics Canada, and reported with 95% CIs. Rates of ED visits for TBI by patients with different levels of CCI, rates of visits by different categories of visit disposition, and rates of visits by different types of ambulance transport among the general Ontario population were also calculated and reported with the 95% CI. Poisson regression controlling for age and sex was used to identify significant trends in TBI rates over the 15-year study period. Each statistical analysis was executed using Stata 15 (StataCorp), and $p < 0.05$ was considered statistically significant.

Results

Epidemiological Trends in ED Visits for Fall-Related TBI

Between 2002 and 2017, there were 260,033 ED visits for TBI in those 65 years and older. The overall rate of these visits increased over this time period by 78%, from 689.51 per 100,000 (95% CI 676.5–702.8) to 1229 per 100,000 (95% CI 1215–1243); a significant trend was detected ($p < 0.001$) (Table 1, Fig. 1).

The most common presenting injuries for TBI were unspecified head injuries (51%), followed by open wounds to the head at 30%, and intracranial injuries at 16%. The majority of patients were discharged home (80%), 16% were admitted to reporting hospitals, and 3% were transferred to other acute care facilities. There was a significant increasing trend in the rate of discharge to home, admission to reporting hospital, and transfer to acute care facilities

TABLE 1. General characteristics of visits to EDs for fall-related TBI, 2002–2017

Characteristic	Incidence		Rate per 100,000 People (95% CI)		Percent Change	IRR from Poisson Regression	p Value
	2002	2017	2002	2017			
Overall	10,455	28,144	689.51 (676.5, 702.8)	1229 (1215, 1243)	78.24%	1.04	<0.001
Sex							
Male	3,951	11,653	603.85 (585.4, 622.9)	1131.39 (1111, 1152)	87.36%	1.04	<0.001
Female	6,504	16,490	754.52 (736.5, 773)	1308.9 (1289, 1329)	73.47%	1.04	<0.001
Age in yrs							
65–69	1,302	3,972	298.04 (282.3, 314.7)	531.77 (515.5, 548.5)	78.42%	1.03	<0.001
70–74	1,764	4,149	444.34 (424.1, 465.5)	768.38 (745.4, 792)	72.92%	1.04	<0.001
75–79	2,236	4,631	694.12 (666, 723.4)	1155.42 (1122, 1188)	66.46%	1.03	<0.001
80–84	2,316	5,366	1114.96 (1071, 1161)	1826.04 (1778, 1874)	63.78%	1.04	<0.001
85–89	1,694	5,356	1647.34 (1571, 1727)	2775.2 (2702, 2848)	68.46%	1.04	<0.001
90+	1,143	4,670	2296.42 (2168, 2432)	4052.52 (3939, 4166)	76.47%	1.04	<0.001
CCI							
0–1	0	0	0	0	NA	NA	NA
2–3	5,165	10,708	340.63 (331.5, 350)	467.6 (458.8, 476.5)	37.28%	1.02	<0.001
4+	5,290	17,436	348.88 (339.6, 358.4)	761.5 (750.2, 772.7)	118.26%	1.04	<0.001
Visit disposition							
Home	8,521	22,403	561.96 (550.2, 574)	978.4 (965.7, 991.2)	74.10%	1.03	<0.001
Admitted to reporting hospital	1,540	4,640	101.56 (96.62, 106.8)	202.6 (196.9, 208.5)	99.48%	1.04	<0.001
Transfer, acute care	262	968	17.28 (15.31, 19.5)	42.3 (39.69, 45.02)	144.80%	1.06	<0.001
Transfer, nonacute care	64	64	4.22 (3.306, 5.389)	2.8 (2.189, 3.569)	–33.66%	0.98	0.02
Died in ED	36	51	2.37 (1.715, 3.287)	2.2 (1.694, 2.928)	–7.17%	1.00	0.97
Other	32	18	2.11 (1.495, 2.979)	0.8 (0.4973, 1.243)	–62.09%	0.92	0.02

IRR = incidence rate ratio per 1-calendar-year increment; NA = not applicable.
The subtotals in tables may not always match the overall because of missing data.

($p < 0.001$, respectively; see Table 1). There was also a significant decreasing trend in the rate of nonacute care facilities ($p = 0.02$, Table 1).

Key Demographic Trends

Age and Sex

The study sample was 61% female and 39% male. Over the course of the study, the overall rate of ED visits for fall-related TBI significantly increased for both sexes (Table 1, Fig. 1). However, as shown by Fig. 1, females constantly experienced a higher incidence rate than the overall incidence rate, and males constantly experienced a lower

incidence rate than the overall incidence rate throughout the study period. In terms of the percentage change in incidence rate, there was a more noticeable increase among elderly males in comparison to their female counterparts (87% increase for males vs 73% for females) (Table 1).

As shown by Fig. 2, the incidence rate increased with age over the study period, with the peak rates of fall-related TBI occurring among those in the oldest age categories (90+ and 85–89 years). As shown by Table 1, all age groups experienced significant increases in fall-related TBI incidence rate over the study period—TBI rates in-

FIG. 1. Fall-related elderly TBI rate from 2002 to 2017 among all patients.

FIG. 2. Fall-related TBI rates by age group from 2002 to 2017 among all patients.

FIG. 3. Fall-related elderly TBI rate by sex from 2002 to 2017 among all patients.

creased for all age groups, with those individuals in the 65- to 69-year, 90+-year, and 70- to 74-year groups showing the top 3 highest percentage changes of the TBI incidence rate; 78.42%, 76.47%, and 72.92%, respectively, among both sexes. The 90+-year age group among both sexes however, experienced the highest incidence rates and the second highest overall increase—of 76.47%, from 2296.42 per 100,000 (95% CI 2168–2432) to 4052.52 per 100,000 (95% CI 3939–4166) ($p < 0.001$) (Table 1, Fig. 1).

Figures 3 and 4 show that rates among males and females also increased with age, with the highest rate occurring among the oldest (90+ years) patients and the lowest rate occurring among the youngest (65–69 years) age group each year of the study period. Figure 4 shows that the proportions of rates by age group remained stable throughout the study period in each sex.

FIG. 4. Pie charts of fall-related TBI rates per 100,000 people by age for each sex in 2002/03 and 2016/17 among all patients. The proportions of rates by age group remained stable throughout the study period in each sex.

Trends in Comorbidity, Visit Disposition, and Ambulance Transport

Over the study period, patients with TBI presented with continually increasing ambulance transport use and comorbidity indexes. All patients had a CCI of at least 2. Particularly notable was the 118% increase in the rates of patients with 4+ CCI, from 349 per 100,000 (95% CI 339.6–358.4) to 762 per 100,000 (95% CI 750.2–772.7) ($p < 0.001$) (Table 1) between 2002 and 2017.

The visit disposition may reflect the severity of the injury. As Table 1 shows, of those patients who presented to the ED, there was a 74% increase in rates of those discharged home, from 561.96 per 100,000 (95% CI 550.2–574) to 978.4 per 100,000 (95% CI 965.7–991.2) ($p < 0.001$). Substantial increases were also noted in patients who were later admitted to the reporting hospital (99% increase, from 101.56 per 100,000 (95% CI 96.62–106.8) to 202.6 per 100,000 (95% CI 196.8–208.5); $p < 0.001$) or transferred to other acute care facilities (144.80% increase from 17.28 per 100,000 [95% CI 15.31–19.5] to 42.3 per 100,000 [95% CI 39.69–45.02]; $p < 0.001$). The change in visit dispositions of those who died was not significant.

Furthermore, ambulance transport may also be used as a proxy for injury severity, because more severely injured patients are more likely to be transported via ground and/or air transport. As illustrated in Table 2, over the 15-year period, patients transported via air decreased by 93% ($p < 0.001$), as did those transported by a combination of air and ground (15%; $p = 0.34$). Ground transportation, on the other hand, significantly increased (110%; $p < 0.001$) between 2002 and 2017, and a 52% increase was also seen in the incidence of individuals receiving no ambulance transport.

Seasonal and Time Trends

There was a fairly even distribution of ED visits for fall-related TBI throughout the study period, with a slightly higher prevalence occurring from July to September (26%) and October to December (26%). Approximately one-quarter of the total fall-related TBI incidents were reported between the months of January and March (25%) and the months of April and June (24%). Between 2002 and 2017, substantial and significant ($p < 0.001$) changes were noted in the incidence rate reported in each month category; however, the period from January to March had

TABLE 2. Characteristics of visits to EDs for fall-related TBI by month, time distribution, and ambulance transport, 2002–2017

Characteristic	Incidence		Rate per 100,000 People (95% CI)		Percent Change	IRR from Poisson Regression	p Value
	2002	2017	2002	2017			
Month							
Jan–Mar	2,354	6,967	155.24 (149.1, 161.6)	304.3 (297.2, 311.5)	96.01%	1.04	<0.001
Apr–June	2,554	6,814	168.43 (162, 175.1)	297.6 (290.6, 304.7)	76.68%	1.04	<0.001
July–Sept	2,803	7,014	184.85 (178.1, 191.8)	306.3 (299.2, 313.5)	65.69%	1.03	<0.001
Oct–Dec	2,744	7,338	180.96 (174.3, 187.9)	320.4 (313.1, 327.8)	77.05%	1.04	<0.001
Hour							
00:00–03:59	683	1,813	45.04 (41.79, 48.55)	79.2 (75.5, 82.8)	75.83%	1.04	<0.001
04:00–07:59	606	1,917	39.96 (36.91, 43.28)	83.7 (80.0, 87.5)	109.42%	1.05	<0.001
08:00–11:59	2,169	6,092	143.04 (137.2, 149.2)	266.05 (259.4, 272.7)	85.98%	1.04	<0.001
12:00–15:59	2,846	7,593	187.69 (180.9, 194.7)	331.6 (324.2, 339)	76.67%	1.03	<0.001
16:00–19:59	2,502	6,467	165.00 (158.7, 171.6)	282.4 (275.6, 289.3)	71.14%	1.03	<0.001
20:00–23:59	1,649	4,222	108.75 (103.6, 114.1)	184.4 (178.8, 189.9)	69.56%	1.04	<0.001
Ambulance transport							
Air	165	18	10.88 (9.343, 12.67)	0.78 (0.42, 1.15)	−92.83%	0.84	<0.001
Combination	15	19	0.98 (0.5995, 1.632)	0.83 (0.46, 1.20)	−15.31%	0.98	0.34
Ground	5,159	16,393	340.24 (331.1, 349.6)	715.9 (705, 726.8)	110.41%	1.05	<0.001
None	5,116	11,714	337.40 (328.3, 346.8)	511.6 (502.4, 520.8)	51.62%	1.04	<0.001

the highest percentage change of 96.01% in incidence rate (Table 2).

Based on the assumption that individuals would seek immediate help after a fall, the time of ED visit may also act as a proxy for time of injury. As illustrated in Table 2, throughout the study period, most of the total ED visits occurred between 08:00 and 19:59 (21% 08:00–11:59, 27% 12:00–15:59, and 23% 16:00–19:59). Statistically significant percent changes were evident in all time slots for fall-related TBIs between 2002 and 2017 and ranged from 70% to 109%. The most noticeable increase was observed in the 04:00–07:59 (109% increase) and 08:00–11:59 (86% increase) time slots (Table 2).

Trends in Hospital Admissions

The rate of hospital admissions for patients with fall-related TBI presenting to the ED increased by 99%, from 101.56 (95% CI 96.62–106.8) to 202.6 per 100,000 (95% CI 196.8–208.5) over the 15-year study period ($p < 0.001$). Both sexes experienced significant increases in the admission rate over the study period ($p < 0.001$); however, males experienced both a higher rate and higher percentage change than females (Table 3). All 6 age groups experienced significant increases in the admission rate over the study period ($p < 0.001$). There was also a significant increase of 74.91% in incidence rate of fall-related TBI presenting to the ED without hospital admission, from 585.57 per 100,000 (95% CI 573.6–597.8) to 1024.23 per 100,000 (95% CI 1011–1037) (Table 4).

Discussion

Our study confirms that TBI rates related to falls of individuals 65 years of age and older are increasing over time in both sexes. We found that among individuals over

the age of 65 years, the rate of fall-related TBI has consistently increased with age since 2002, with the highest percentage of increase in the 65- to 69-year age group and the highest rate of incidence in the 90+-year age group. Rates of TBI increased by 66% over the course of our study; comparably, a 12-year study done in Oklahoma from 1992 to 2003 showed that the rate of TBIs in the elderly increased by 79%.⁵ These similarities stress that fall-related TBI in populations aged 65 years and older is a universally growing problem.

The degree of increasing rates in fall-related TBI varied with sex. Prior research shows that among those under the age of 65 years, males demonstrate a higher fall risk and experience worse outcomes; however, from ages 65 to 84 years, females have a higher fall risk.^{9,11} These findings were confirmed in our research; two-thirds of patients with fall-related TBI were female. Additionally, although an increase in fall-related TBI injury rate was observed in both sexes over the 15 years, the injury rate was consistently greater in females than males each year. However, our study also demonstrated that males had a higher percent change in injury incidence rate compared to females, suggesting an accelerating trend for increasing falls in males in recent years. Whether this is related to more active lifestyles among aging males requires further study. Furthermore, although the rates of fall-related TBI and injury varied during the study, females and the 90+-year age group were consistently the group most at risk of fall-related TBI. There were no significant differences in fall-related TBIs according to season or time, but rates increased during each subsequent time period during the study.

Fall-related TBI incidence rates are increasing and the burden of head trauma is significant; however, sufficient prevention programs and treatment options are not grow-

TABLE 3. Characteristics of patients with fall-related TBI who were admitted to reporting hospitals, 2002–2017

Characteristic	Incidence		Rate per 100,000 People (95% CI)		Percent Change	IRR from Poisson Regression	p Value
	2002	2017	2002	2017			
Overall	1540	4640	101.56 (96.62, 106.8)	202.6 (196.8, 208.5)	99.48%	1.04	<0.001
Sex							
Male	698	2226	106.68 (99.06, 114.90)	216.12 (207.30, 225.30)	102.58%	1.05	<0.001
Female	842	2414	97.68 (91.30, 104.50)	191.61 (184.10, 199.40)	96.16%	1.04	<0.001
Age in yrs							
65–69	172	457	39.37 (33.91, 45.71)	61.18 (55.83, 67.05)	55.40%	1.03	<0.001
70–74	203	545	51.13 (44.57, 58.67)	100.93 (92.81, 109.8)	97.40%	1.04	<0.001
75–79	315	750	97.78 (87.57, 109.2)	187.12 (174.2, 201.1)	91.36%	1.04	<0.001
80–84	386	974	185.83 (168.2, 205.3)	331.45 (311.3, 352.9)	78.36%	1.05	<0.001
85–89	274	1017	266.45 (236.8, 299.9)	526.95 (495.6, 560.3)	97.77%	1.04	<0.001
90+	190	897	381.73 (331.3, 439.9)	778.40 (729.3, 830.8)	103.91%	1.05	<0.001
CCI							
0–1	0	0	0	0	NA	NA	NA
2–3	626	1271	41.28 (38.18, 44.65)	55.50 (52.54, 58.64)	34.44%	1.02	<0.001
4+	914	3369	60.28 (56.5, 64.31)	147.13 (142.2, 152.2)	144.08%	1.06	<0.001

ing accordingly. Given that the annual expenses associated with TBIs are extensive—approximately \$56 billion in the United States—treating and preventing TBI has become a more prevalent and pressing topic.¹ Moreover, the rapidly growing elderly population is predicted to almost double from 12% to 22% of the world's population between 2015 and 2050, thus making the need for efficient and effective prevention and treatment even more significant.⁶ Compounding this situation, after the initial recovery from a TBI, patients may still experience a decline in neurological function that is more significant than normal age-related changes. Sustaining a TBI may be associated with a higher risk of dementia or Alzheimer disease in the future.¹⁸ TBIs are therefore likely to place larger strains and costs

on the healthcare system over time. The implications of our results are significant for providing service delivery, and highlight the need for heightened prevention efforts for these populations.

Our results show a significant increase of patients with a 4+ CCI and that all patients with fall-related TBI in Ontario had a 2+ CCI. The percent change of patients with a 4+ CCI was far greater than the percent increase of patients with a 2–3 CCI; 118% compared to 37%. There was no significant change in the ICD-10 codes that would have affected this comorbidity index shift. In 2012 Grundstrom et al. suggested that the accumulation of risk factors themselves increased the fall risk, but not intrinsically aging itself.⁹ An American study found that 87.2% of elderly

TABLE 4. Characteristics of patients with fall-related TBI who were not admitted to reporting hospitals, 2002–2017

Characteristic	Incidence		Rate per 100,000 People (95% CI)		Percent Change	IRR from Poisson Regression	p Value
	2002	2017	2002	2017			
Overall	8,879	23,453	585.57 (573.6, 597.8)	1024.23 (1011, 1037)	74.91%	1.04	<0.001
Sex							
Male	3,229	9,399	493.51 (476.8, 510.8)	912.54 (894.4, 931.1)	84.91%	1.04	<0.001
Female	5,650	14,053	655.46 (638.6, 672.7)	1115.46 (1097, 1134)	70.18%	1.03	<0.001
Age in yrs							
65–69	1,126	3,511	257.76 (243.2, 273.2)	470.05 (454.8, 485.8)	82.36%	1.04	<0.001
70–74	1,555	3,594	391.70 (372.7, 411.6)	665.60 (644.3, 687.6)	69.92%	1.04	<0.001
75–79	1,916	3,874	594.79 (568.8, 621.9)	966.55 (936.7, 997.3)	62.50%	1.03	<0.001
80–84	1,921	4,383	924.80 (884.5, 966.9)	1491.53 (1448, 1536)	61.28%	1.04	<0.001
85–89	1,415	4,328	1376.03 (1307, 1449)	2242.54 (2177, 2310)	62.97%	1.03	<0.001
90+	946	3,763	1900.63 (1784, 2024)	3265.44 (3164, 3370)	71.80%	1.04	<0.001
CCI							
0–1	0	0	0	0	NA	NA	NA
2–3	4,527	9,423	298.56 (290, 307.4)	411.52 (403.3, 419.9)	37.83%	1.02	<0.001
4+	4,352	14,030	287.02 (278.6, 295.7)	612.72 (602.7, 622.9)	113.48%	1.05	<0.001

patients with TBI had a 0–2 CCI and only 12.8% had an index of 3+, suggesting that patients with TBI in Ontario have more comorbidities recorded in administrative data sets compared to those in the United States. In support, in 2015 Pefoyo et al.¹⁹ found that patients with 3+ comorbidities increased by 40% in Ontario between 2003 and 2009. There could be multiple reasons for this, including better record-keeping in Ontario, related to hospital reimbursements from the government payer. Although risk factors like age and sex are nonmodifiable, risk factors such as comorbidities can be modified with prevention over the longer term. As people live longer, it will become increasingly important to work on reducing comorbidities at earlier ages, in order to help reduce the risk of fall-related injuries as generations age. Therefore, working to prevent the development of comorbidities that develop over decades would be likely to provide dividends many years into the future in preventing fall-related injury. Whether governments and others in society will heed this call to keep populations healthy earlier in life to prevent negative health effects later will require time and future study.

Our results showed that approximately 16% of patients visiting the ED with fall-related TBI are admitted to the hospital. The factors associated with increasing hospitalization were male sex, 4+ CCI range, and increasing age. That older and sicker patients are admitted after fall-related TBI is not surprising; however, clinicians are often faced with predicting outcomes, and therefore counseling substitute decision-makers with potential therapeutic options such as whether to engage in admission to intensive care, invasive monitoring, and mechanical ventilation. Such counseling is often difficult because prior studies often did not include those older than 80 years, so prediction algorithms are even more inaccurate in smaller subsets of patients, and those that exist are subject to the critical “self-fulfilling prophecy” flaw seen in all prognostic studies in TBI.

In 2017 there were 101.04 per 100,000 more admissions to hospital than there were in 2002. Extrapolating a continued rise of 5.28% per year in the rate of hospitalization would mean that by 2030, there will be an extra 327.39 per 100,000 admissions to hospital (a 62% increase from 2016) and an extra 1618.93 per 100,000 visits to EDs for fall-related TBI (a 32% increase from 2016). These data clearly have implications for the economics of delivering care to this group.

Implications

The changes we have identified have significant implications for the healthcare system and delivery of care to this age demographic. To this end, our work suggests that this trend we have identified will also have wide-ranging implications for rehabilitation and long-term care and ultimately to burdens to society. Survey data have shown that Canada ranks last among 7 industrialized countries in delivery components of chronic care,²⁰ so even for a rich country like Canada, the economic impacts will be significant. If these trends are paralleled in lower-income countries, the effects on economics and healthcare systems can be profound.

These results also highlight the need for all healthcare

providers to work with aging patients and especially those with comorbidities to engage them and their families in developing appropriate goals of care before significant health-related events such as TBI occur. Once TBI occurs, neurosurgeons will increasingly need robust, high-level data with which to counsel patients and families on outcome prediction with various treatment paradigms. Given the increasingly prevalent “active octogenarians” and “active nonagenarians” appearing in neurosurgical wards and critical care areas, more randomized controlled data appropriately powered in this age group will be required. These data will not only be required to provide sound advice to families and patients, but also to help develop health policies around triaging scarce resources.

These facts point to the need for concerted efforts to prevent these injuries in this age demographic and to advance policy decisions to support the efforts. From the perspective of prevention of falls, there is emerging evidence that prevention needs to start very early, particularly in terms of building cognitive and physical reserve as people age. The 90+ Study showed that there is a clear association between exercise at age 60–70 years and lower risk of falling at age 90+ years.²¹ Body strength and balance, avoidance of polypharmacy, and ensuring that physical environments promote safe mobility are key ingredients to prevention that require advanced planning and policy changes on a population level. All of this points to a critical need to aim prevention not only at this age demographic but also at earlier generations to avoid and avert this trend in coming generations. Neurosurgeons are poised to lead these efforts at prevention and should take up the challenge everywhere. Should this broad call to action not be heeded, our work suggests that the personal and societal burdens of TBI in older populations will progressively challenge healthcare systems globally.

Limitations

There are limitations to this study. First, it was based on data from the NACRS ED data set, and so may not include all fall-related TBIs because some mild cases may not be treated or may be treated in outpatient facilities, not necessitating an ED visit. Likewise, fatal falls for which patients are not brought to the ED will not be counted in this data set. Furthermore, certain groups from certain geographic areas may not visit the ED to the same degree as occurs in other geographic areas. Miscoding or undercoding may also have limited the detailed interpretation of the injuries, because “other unspecified head injuries” (S09.7–S09.9) accounted for 51% of the ICD-10 diagnoses, which might result in misclassification of head injuries as TBI. There is also significant variation in TBI rates depending on the chosen ICD-10 codes, thus exemplifying the need for a standardized definition of TBI to ensure accurate comparisons. Measures of injury severity such as the Glasgow Coma Scale score are inconsistently coded, and so we depended on measures such as admission to hospital as a proxy of severity. The goals of this study were to describe the epidemiological trends and implications on a population-based level. The database does not include information on surgical procedures and that would be beyond the focus of the present study. Despite such intrinsic

limitations of the database, NACRS does cover 98% of all ED visits in a population of 13.9 million people, and so remains a valuable resource in the study of TBI epidemiology across the whole population as opposed to a single or even a number of centers.

Conclusions

In this population-based, epidemiological study of ED visits for fall-related TBI in patients aged 65 and older over a 15-year period, we found increasing rates of ED visits, increases in comorbidities, and increases in rates of hospitalization among both sexes and in all age groups. These falls are placing strains and, if unabated, will place increasingly greater strains on the healthcare system, on the long-term care system, and on the broader society. These findings have significant implications for neurosurgical resources; they emphasize that health professionals should work proactively with patients, families, and caregivers to clarify goals of care, and they also outline the need for more high-level and, preferably, randomized evidence to support outcomes-based decisions. Additionally, the findings highlight the urgent need for improved population-based measures for prevention in not only this age demographic but in younger ones, and call attention to the need for changes in planning health service delivery and long-term care.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Cusimano, Saarela. Acquisition of data: Cusimano, Hart, Zhang, McFaull. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Cusimano. Statistical analysis: Saarela, McFaull. Administrative/technical/material support: Hart, Zhang, McFaull. Study supervision: Cusimano.

Correspondence

Michael D. Cusimano: Unity Health Toronto, ON, Canada. injuryprevention@smh.ca.